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VOLUME VIII.
1919-20.

WITH TWENTY PLATES.

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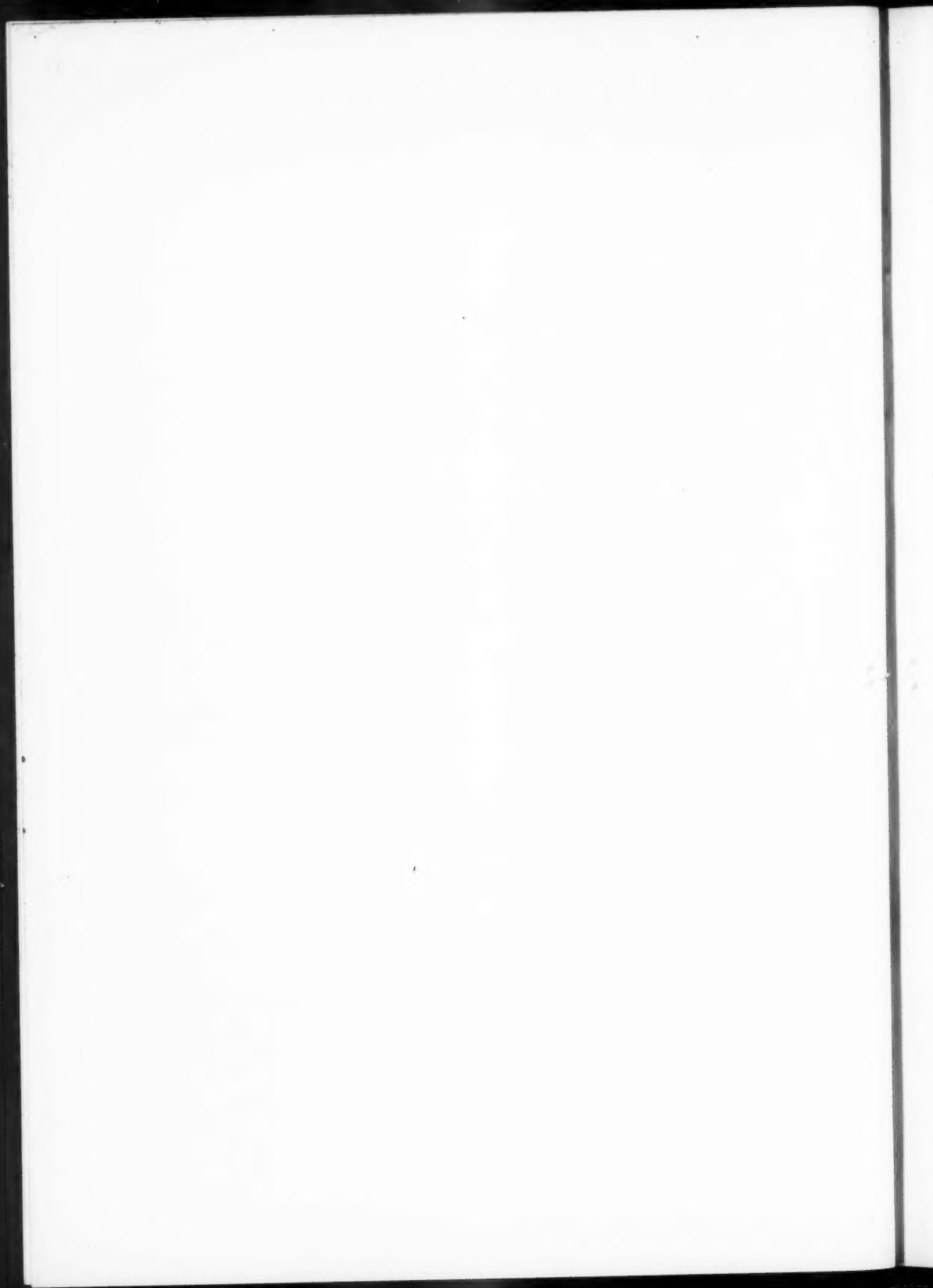
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MINUTES OF PROCEEDINGS
OF THE
ROYAL SOCIETY OF SOUTH AFRICA.

REPORT OF THE HON. GENERAL SECRETARY FOR THE YEAR ENDING
DECEMBER 31, 1916.

Seven Ordinary Meetings, the Annual and the Anniversary Meetings, were held during the year, and the following papers were read:

"Note on Pfaffians Connected with the Difference-product," by Sir THOMAS MUIR.

"Note on the so-called Vahlen Relations between the Minors of a Matrix," by Sir THOMAS MUIR.

"On the Development of the Perturbative Function in the Theory of Planetary Motion," by R. T. A. INNES.

"A Contribution to our Knowledge of the National Game of Skill of Africa," by P. A. WAGNER.

"A Survey of the Scorpion Fauna of South Africa," by JOHN HEWITT.

"Note on a Petiole and Portion of the Lamina of *Cotyledon orbiculata* Functioning as a Stem," by S. SCHÖNLAND.

"Oecological Notes on the District of Manubie, Transkei," by W. T. SAXTON.

"Note on the Radiations emitted by Degenerating Tissues and Note on the Ionisation produced by Degenerating Nerve-Muscle Preparations," by J. STEPH. VAN DER LINGEN.

"Note on Protective Resemblance in Post-Larval Stages of some South African Fishes," by J. D. F. GILCHRIST.

"On the Morphology of the Female Flower of *Gnetum*," by H. H. W. PEARSON.

"Heart Rot of *Ptaeroxylon utile* (Sneezeewood) caused by *Fomes rimosus* (Berk)," by PAUL A. VAN DER BIJL.

"On *Pelodrilus Africanus*, a new Haplotaxid from South Africa," by E. J. GODDARD.

"Note on *Polysaccum crassipes*, a Common Fungus in Eucalyptus Plantations around Pretoria," by PAUL A. VAN DER BIJL.

"The Granite of the Schapenberg, Somerset West," by A. R. E. WALKER.

"On the Radial Lines in Röntgen Interference Patterns," by J. STEPH. VAN DER LINGEN.

"Some Observations on *Ozobranchus branchiatus*," by E. J. GODDARD.

"On some Stages in the Life History of Gnetum," by H. H. W. PEARSON and MARY R. H. THOMSON.

"The Theory of Automatic Regulators," by H. BOHLE.

"Variation in the Mylabridae Illustrating a New Theory of Evolution based on Mendelism," by T. F. DREYER.

"African Myxomycetes," by Miss A. V. DUTHIE.

"On Hybrid Forms in the Genus *Satyrium*, with Descriptions of Two New Forms," by Miss A. V. DUTHIE.

"Ionisation of Gases and the Absorption of Röntgen Rays," by LEWIS SIMONS.

"Note on the Occurrence of Daphnin in the Arthrosolen," by M. RINDL.

The Society has awarded, on the recommendation of the General Committee for Grants-in-Aid of Research, the following grant: £50 to Mr. J. S. VAN DER LINGEN, for continuation in research work on Radiology generally.

During the past year further progress has been made with the cataloguing of the Society's Library. The publications of the undermentioned Societies have been examined and catalogued, and communications are proceeding with the Societies regarding filling up of blanks.

Royal Society of New South Wales.

Linnean Society of New South Wales.

Australian Museum, Sydney.

Royal Society of South Australia.

Royal Geographical Society of Australasia.

Adelaide Observatory.

University of Sydney.

Melbourne Observatory.

Royal Society of Victoria.

Victoria Public Library, Museum and National Gallery.

National Museum, Melbourne.

Tasmania, Department of Mines.

Royal Zoological Society of New South Wales.

New Zealand Institute.

Royal Society of Tasmania.

Queensland Museum.

Royal Society of Queensland.

Australasian Association for the Advancement of Science.

Vol. V, Parts 3, 4 and 5, of the Society's Transactions have been issued during the year. Other parts which would have been issued in 1916 have been unavoidably delayed owing to the unusual conditions prevailing at present.

The number of Honorary Fellows is 3; Fellows, 50; Members, 168. Dr. Percy A. Wagner, Dr.Ing., B.Sc., has been elected a Fellow in 1916.

The Society regrets to have to record the death, since the 1915 Anniversary Meeting, of Mr. R. Trimmen, Honorary Fellow, Professor H. H. W. Pearson, Fellow, and Mr. H. A. Fry and Dr. C. McGowan Kitching, Members.

WM. A. JOLLY,

Hon. General Secretary.

ANNIVERSARY MEETING.

The Anniversary Meeting of the Society was held on Wednesday, March 21st, 1917, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

The President, Dr. L. PÉRINGUEY, was in the Chair.

The Report of the Hon. General Secretary was submitted and adopted.

The Report of the Hon. Treasurer was submitted and adopted.

The following were elected Members of Council for the year 1917:

Dr. A. JASPER ANDERSON. Dr. W. A. JOLLY.

Dr. W. A. CALDECOTT. Mr. C. P. LOUNSBURY.

Dr. G. S. CORSTORPHINE. Dr. L. PÉRINGUEY.

Dr. L. CRAWFORD. Dr. W. F. PURCELL.

Dr. A. L. DU TOIT. Dr. S. SCHÖNLAND.

Mr. S. S. HOUGH. Dr. B. ST. J. VAN DER RIET.

Dr. L. PÉRINGUEY was elected President.

Dr. L. CRAWFORD, Hon. Treasurer.

Dr. W. A. JOLLY, Hon. General Secretary.

The President announced his nomination, as Vice-Presidents, of Dr. A. Jasper Anderson and Dr. G. S. Corstorphine.

TREASURER'S ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1916.

| RECEIPTS. | | EXPENDITURE. | |
|--|-----------|---|-----------|
| £ | s. d. | £ | s. d. |
| To Balance in Bank as per Pass Book... | 116 8 3 | By Publications ... | 486 11 0 |
| " Subscriptions received in 1916: | | " Landing Charges, etc. ... | 11 18 3 |
| for 1914, 2 Fellows at £2, 2 Country | | " Research Grants and Expenses ... | 78 18 9 |
| Members at £1 ... | 6 0 0 | " Cost of Stamps on retaining £800 for one year on | |
| for 1915, 4 Fellows at £2, 3 Town Members | | " Fixed Deposit at Standard Bank ... | 0 4 0 |
| at £2, 11 Country Members at £1, | | " Payments in connection with Grant to Professor | |
| balance 1 Country Member 19s., balance | | " Pearson for Botanical Exploration in Namaqualand, | |
| 1 Country Member 16s. ... | 26 15 0 | closing account ... | 44 6 3 |
| for 1916, 41 Fellows at £2, balance 1 | | " Compilation for International Scientific Catalogue of | |
| Fellow £1 16s., 42 Town Members at | | " Papers ... | 25 0 0 |
| £2, balance 1 Town Member £1 18s., | | " Clerical Assistance and Work in Library ... | 55 0 0 |
| 81 Country Members at £1, balance | | " Local Printing and Stationery ... | 33 6 10 |
| 1 Country Member 19s., balance 1 | | " Postages and Petties ... | 48 16 3 |
| Country Member 18s., £1 extra sub- | | " Bank Charges for Commissions, Ledger Fees, Cheque | |
| scription from Country Member elected | | Book less Commissions paid by Members ... | 1 16 2 |
| Fellow ... | 253 11 0 | " Hire of Room for Meetings and Caretaker, 1916 | 5 15 6 |
| for 1917, 1 Country Member at £1, part | | " Cash, Entrance Fees received 1916, put into Post Office | |
| subscriptions 3s. ... | 1 3 0 | Savings Bank ... | 10 0 0 |
| | | " Balance in Bank as per Pass Book | 217 12 9 |
| Entrance Fees received, 10 new Members | 287 9 0 | | |
| " Sale of Publications to Government | 10 0 0 | | |
| " Sales of Publications otherwise | 100 0 0 | | |
| " Sales of extra Reprints of Papers | 38 12 6 | | |
| " Government Grant, 1915-6 | 34 16 0 | | |
| " Government Grant, 1916-7 | 50 0 0 | | |
| " Interest on Fixed Deposit in Standard | 50 0 0 | | |
| Bank, 1915-16 | 32 0 0 | | |
| " Cash drawn from Post Office Savings Bank | 300 0 0 | | |
| | £1019 5 9 | | £1019 5 9 |

ASSETS AND LIABILITIES AS AT DECEMBER 31, 1916.

| ASSETS. | | LIABILITIES. | |
|--|-------------------|--|-----------------|
| | £ s. d. | | £ s. d. |
| Money at Standard Bank on Fixed Deposit at 4 per cent. | 800 0 0 | Subscriptions, whole or in part, received for 1917 | 1 3 0 |
| Money in Post Office Savings Bank, Life Subscriptions and Entrance Fees | 144 0 0 | Balance Research Grant voted in 1914 to Miss M. Wilman | 25 0 0 |
| Money in Post Office Savings Bank, at call, with interest to March 31st, 1916 | 131 8 6 | Earmarked for Expense of Publishing, as a part of the | |
| Balance in Standard Bank, as per Pass Book | 217 12 9 | Transactions, a reproduction of a Bushman Painting (Council Minutes, May 12, 1915) a sum not exceeding | 350 0 0 |
| Petty Cash in hands of Hon. Secretary | 1 15 3 | Balance from 1912 Conversazione carried forward towards the expenses of future Conversazione in Capetown | 7 4 0 |
| Arrears of Subscriptions, as in Statement for 1915, due at beginning of 1916, £35 15s., less £32 15s. paid in year and £10 struck off as irrecoverable | 13 0 0 | | |
| Arrears of 1916 Subscriptions | 63 0 0 | | |
| Money due for Sale of Publications | 2 16 10 | | |
| Money due for Sale of Extra Reprints of Papers | 4 5 0 | | |
| | <u>£1377 18 4</u> | | <u>£383 7 0</u> |

LAWRENCE CRAWFORD, Hon. Treasurer.

We have audited the accounts and checked the vouchers of the Royal Society of South Africa for the year 1916, and find the same, to the best of our belief, correct.

February 12, 1917.

S. S. HOUGH.
ALEXANDER BROWN.

NOTE.—Owing to the abnormal delay in sending out the 'Transactions' of the Society, an account falls to be paid in 1917 for the printing of Vol. V, Pt. 6, and Vol. VI, Pt. 1, ordered in 1916. This account is roughly estimated to be £550.

ORDINARY MEETING.

An Ordinary Meeting was held on March 21st, after the Anniversary Meeting.

The PRESIDENT was in the Chair.

The Minutes of the Ordinary Meeting held on October 18th, 1916, were confirmed.

Dr. E. T. STEGMANN, B.A., D.Sc., and Mr. S. H. SCAIFE were nominated for election as members.

COMMUNICATIONS:

"Note on Palmström's Generalisation of Lamé's Equation," by Sir THOMAS MUIR.

"*Mestoma antarcticum* from Bloemfontein (sp. nov.)," by T. F. DREYER.

This paper contains a description of a very slender worm, tapering towards both ends, and, when fully extended, about 7 mm. in length and about 1 mm. broad, found in a small pond on clay soil near Bloemfontein. The specimen shows an almost negligible amount of variation from *M. mutabile* from Tierra del Fuego; whether this similarity is due to parallel evolution or to a former land connection or to dispersal by birds must remain an open question.

"Colour and Chemical Constitution: A Study of the Phthaleins and Related Compounds," by JAMES MOIR.

ORDINARY MONTHLY MEETING.

An Ordinary Meeting was held on Wednesday, April 18th, 1917, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

The President, Dr. L. PÉRINGUEY, was in the Chair.

The Minutes of the previous meeting were confirmed.

Prof. R. B. YOUNG was admitted a Fellow of the Society.

Dr. E. T. STEGMANN and Mr. S. H. SCAIFE were elected members.

EXHIBITS.

The President exhibited polychrome and monochrome paintings, executed on river-water and other flat stones found in exploring caverns occupied by Strand Looper Snails along the littoral of the Cape. These paintings are of a type superior in some cases to the well-known parietal paintings of the Bushmen of the interior. They were found lying, and in some cases with the painting downwards, on or slightly above the flexed skeleton. That the paintings were executed for inhumation purposes, and were not detached

from painted scenes on parietal surfaces is proved by the painting being continued on the side of the fractured slab. The technique and pigments are, however, those of the inland Bush, and this alone would go far to prove the identity of the Strand Looper with the Bushman as one race. The Bush painted and graved; the Hottentot neither paints nor graves. Singularly enough the name Hottentot should apply to that race which is now dubbed Bushman. One of the scenes corroborates details of the Hottentot (Strand Looper) deportment given by Captain Beaulieu, who touched at Table Bay in 1621.

Mr. S. H. HAUGHTON exhibited an almost complete skeleton of a specimen of fossil reptile from the middle Beaufort Beds.

The specimen exhibited was obtained by Dr. A. L. du Toit in Natal, and was associated with portions of skulls of undoubted species of *Lystrosaurus*. Apart from the fact that the skull and lower jaw are associated with the larger part of the skeleton, the specimen is of interest in that it seems to form a link between some Dicynodonts of the *Cistecephalus* zone and *Lystrosaurus* proper. The snout is bent down as in the latter genus, but it is not so greatly elongate. The relations of the bones of the top of the skull are typically Dicynodont. The upper border of the ilium is notched as in *Lystrosaurus*, but there are only two notches instead of three. In view of its intermediate character, it has been thought advisable to create for it a new genus *Prolystrosaurus*, which is also considered to include the form described as *Dicynodon strigops*.

Mr. K. H. BARNARD exhibited shells collected in Namaqualand by Dr. Rogers.

Examples of most of the known species and varieties of the *Dorcasiinae* were shown together with some specimens of the allied sub-families from other parts of the world. Remarks were made on the supposed phylogeny of the family according to the recent anatomical researches of Watson and on the variation in the Helicoid form according to habitat.

Dr. A. L. du Toit exhibited some hybrid graphite-bearing rocks from Natal.

These are found at the Ingeli and near Ladysmith, and have been produced by the intrusion of dolerite into carbonaceous shale. The latter has been disrupted, and all stages are seen up to a breccia in which small fragments of shale are embedded in an igneous matrix, the sedimentary rock having been completely re-crystallised with the development of graphite and silicates, while the dolerite by reaction and incorporation of silica from the inclusions has been acidified and is now pale in colour.

COMMUNICATIONS.

"Note on the Expansion of the Product of Two Oblong Arrays," by Sir THOMAS MUIR.

The form taken by Binet and Cauchy's well-known expansion of the year 1812 is that of a sum of products of pairs of determinants: the form of the expansion now given is that of an aggregate of single determinants. The relation between the two is explained and a historical remark added.

"Notes on Radiation of Crystals," by J. STEPH. VAN DER LINGEN.

(a) Radiation patterns of the transformation of magnesium hydroxide to magnesium oxide. The patterns show that the reflecting planes of the crystal are disturbed when water is driven off. The patterns show that the "spots" become drawn out into radial lines, and that these radial lines reflect the intensity of the X-ray spectrum. These observations show that Friedrich's two-dimensional grating may only be attributed to crystals under definite physical conditions.

(b) Diamond tests by radiation patterns.

The following stones were examined:

"Macle," "spotted" stone, "spotted rejection" stone, and an "inferior brown block" with a spot in it. The patterns show that a "spot" in a stone causes a discontinuity in the intensity of individual spots of the patterns, and that a fracture of the lattice causes a discontinuity of the spots so that they now represent irregular markings on the plate. An ideal diamond's pattern shows a uniform intensity in all the spots.

(c) Bultfontein Apophyllite—(1) ideal, and (2) showing a cleavage crack along a cleavage plane.

The flaw causes the spots of the "flawed" crystal to present a nebular appearance, whereas the ideal stone shows a uniform distribution of intensity in the elliptic spots. This represents a case of discontinuity in the lattice normal to the incident rays.

(d) Serpentine, malachite and pseudomorph quartz.

Serpentine shows a regular "radial line" pattern symmetrical to a line parallel to the threads of the crystal. This indicates that serpentine is not triclinic unless every specimen examined was a "twin."

Malachite shows three "lines" parallel to the threads and some minor radial lines normal to the former deviating slightly from the normal.

Crocidolite: A long exposure shows that it is micro-crystalline and that the elementary units have a tendency to favour a direction parallel to the threads.

(e) A square plate of iodine showed, after an exposure of about an hour, diffraction, a phenomenon similar to that described by Prof. Laub of Buenos Ayres.

In this case the plate shows diagonal lines of zero intensity.

"A Summary of the Distribution of the Genera of South African Flowering Plants (with special reference to the Flora of the Uitenhage and Port Elizabeth divisions)," by S. SCHÖNLAND.

This is to a large extent based on published data checked and enlarged,

however, by the author's personal knowledge. It was compiled in connection with a study of the flora of Uitenhage and Port Elizabeth, but it is hoped that it may be welcome to other botanists who desire to have readily available a summary showing the general trend of distribution of South African genera.

"Note upon the Endocranial Cast obtained from the Ancient Calvaria found at Boskop, Transvaal," by G. ELLIOT SMITH.

The author describes the cast representing the form of the cranial cavity of the skull-cap from Boskop described by Mr. S. H. Haughton, and states that whatever the date of the Boskop remains may be, the evidence now in our possession suggests that this early inhabitant of the Transvaal represents the type of the immediate ancestors of the men of the Upper Palaeolithic Age, possibly somewhat modified in the course of his southern migration. It probably represents the earliest (not necessarily in actual age) known phase of *Homo sapiens* in the course of his transformation from a condition analogous to that of Neanderthal man to that of Cro-Magnon.

ORDINARY MEETING.

An Ordinary Meeting was held on Wednesday, June 20th, 1917, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

The President, Dr. L. PÉRINGUEY, was in the Chair.

The Minutes of the previous meeting were confirmed.

Mr. J. BOYD, F.I.C., A.R.T.C. (Glasgow) was elected a member of the Society.

Notice of Motion was given by Mr. C. W. Mally with reference to the preservation of anatomical material.

EXHIBITIONS.

Miss J. E. SMITH, M.Sc., gave an exhibition of some higher fungi and lichens found in South Africa. The exhibits included some interesting forms from the National Botanic Gardens, Kirstenbosch, among them *Tremella frondosa*, *Agaricus deliciosum* (an edible fungus, allied to the mushroom, very common at Kirstenbosch), and a *Peziza*, found inside the stem of a tree fern. Attention was drawn to the diverse adaptations for spore protection and dispersal.

Mr. C. W. MALLY gave an exhibit of the beetle *Formicomus coerules*, which attacks and devours the living pernicious scale. This beetle is not merely a scavenger, but from Mr. Mally's observations it is clear that scale insects are killed by it, and it may be a valuable auxiliary in the destruction of the scale.

COMMUNICATIONS:

"Note on a Case of Hermaphroditism." By H. V. EXNER.

The author describes as a case of hermaphroditism the body of a person of unsound mind, who had the outward appearance of a Kafir girl. The nature of the case was only recognised after a histological study of the genital organs.

"Note on the genus *Terfezia*: A Truffle from the Kalahari. By I. B. POLE-EVANS.

Attention is drawn to the fact that *Choeromyces*, a truffle hitherto unknown to Africa, has recently been reported from South Africa. The author points out that the best known South African truffles belong to the genus *Terfezia*.

The distinction between *Choeromyces* and *Terfezia* is indicated, and a description is given of a truffle (*T. Claveryi* Chat.) recently sent to the author from the Griqualand West district in the Kalahari.

ORDINARY MEETING.

August 15, 1917.

Dr. L. CRAWFORD in the Chair.

The Minutes of the previous meeting were confirmed.

COMMUNICATIONS:

"Note on the Resolvability of the Minors of a Compound Determinant."

By Sir THOMAS MUIR.

"Colour and Chemical Constitution (Part II): The Spectra of the Mixed Phthaleins and of the Sulphone-phthaleins." By JAMES MOIR.

Mixed phthaleins, containing two different phenol residues, one of which is C_6H_4OH , are made with extraordinary ease by boiling paraoxybenzophenone-o-carboxylic acid with any phenol or amine, whether free or substituted. The spectra of 18 new phthaleins of this class are described, and the laws governing the colours are elucidated. This method is an excellent analytical one for identifying phenols and amines and their ethers and derivatives. The spectrum of phenolthymolphthalein is not exactly halfway between those of phenolphthalein and thymolphthalein. The spectra of 5 sulphonephthaleins made from "saccharin" are also described, also 6 more new derivatives of ordinary phenolphthalein (see Part I).

A new general formula for the coloured substances is put forward.

"Kimberley Diamonds: Especially Cleavage Diamonds." By J. R. SUTTON.

This paper is a general and statistical account of the diamonds produced in the mines under the control of the De Beers Company at Kimberley. It

describes the outstanding differences in size, colour, and type, between the yields of the different mines, speaks of coloured diamonds, bort, and especially cleavage diamonds; and advances a view that many diamonds have been naturally broken by the unequal expansion of themselves and mineral inclusions. It appears that brown diamonds have shown a particular disposition to come up broken from the deeper levels of the Wesselton mine (though the ratio of colourless cleavage to colourless stones also increases with depth of mining), but the author doubts the common assertion that brown or smoky diamonds are markedly liable to spontaneous fracture.

"On the Phanerogamic Flora of the Divisions of Uitenhage and Port Elizabeth." By S. SCHÖNLAND.

This paper is meant to be a companion to the papers published by the late Dr. Bolus and Major Wolley Dod on the Flora of the Cape Peninsula, and by the late Dr. J. Medley Wood on the Flora of Natal. There are 2290 species recorded, of which 98 are considered by the author not to be native. They are distributed over 128 natural orders and 712 genera. There are, however, still large tracts of this area unexplored. Most of the localities quoted are contained in about 600 sq. miles, while the total area is about 2500 sq. miles; much of the remaining tract is, however, covered by fairly uniform karroid succulent vegetation.

"A Lunar Period in the Rates of Evaporation and Rainfall." By J. R. SUTTON.

This paper calls attention to the possibility of a lunar influence governing the evaporation from a water surface, and a lunar period in the incidence of a rainfall. Tables are given showing that as the result of hourly observations of evaporation and rainfall during the 120 lunar months from August, 1899, to April 1909, rainfall has its maximum frequency about the time of moonrise, and its minimum just after moonset; also that the rate of evaporation has a maximum and a minimum, respectively shortly after the moon passes the meridian above and below the horizon.

ANNUAL MEETING.

The Annual Meeting was held on Wednesday, September 26th, 1917, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

The President, Dr. L. PÉRINGUEY, was in the Chair.

Dr. CHARLES EDWARD MOSS, M.A., D.Sc., B.Sc., F.L.S., F.R.G.S., proposed by JOSEPH BURTT-DAVY, R. T. A. INNES, R. B. YOUNG and A. OGG, and—

MR. CHARLES WILLIAM MALLY, M.Sc., F.E.S., F.L.S., proposed by JOSEPH BURTT-DAVY, CHAS. P. LOUNSBURY, W. A. CALDECOTT, R. T. A. INNES, R. B. YOUNG and ROBERT A. LEHFELDT, were elected Fellows of the Society.

ORDINARY MEETING.

An Ordinary Meeting was held on Wednesday, September 26th, 1917, in the Board Room of the South African Association, Church Square, Cape-town.

The President, was in the Chair.

The Minutes of the previous Ordinary Meeting were confirmed.

MISS E. L. STEPHENS exhibited specimens of eleven parasitic plants belonging to the genera *Cassytha*, *Hydnora*, *Viscum*, *Striga*, *Loranthus*, *Hyobanche*, *Harveya* and *Sarcophyte*, and made some brief remarks on their structure and biology.

COMMUNICATIONS:

"Note on the Abnormal Development of the Genital Organs of *Jasus Lalandii*." By W. VON BONDE.

The author records a peculiar abnormality in a male Cape Crawfish.

Three distinct genital apertures are developed, two normally, and a third abnormally, the latter occurring on the fourth walking leg of the right side.

Internally the *vas deferens* of the right bifurcates, sending a branch to the normal opening and a second to the abnormal aperture.

"On the Colour-Octahedron as a Complexity": being suggestions towards a Mathematics of Colour. By G. H. MALAN.

Developing certain ideas of Meinong, who contends that the possibility of representing certain well-known facts in connection with Colour-Psychology by a diagram in the form of an octahedron rests on the presence of certain *a priori* relations incidental to the very nature of colour itself, the writer is led to examine Meinong's contention critically in the light of modern Mathematical Logic (as expounded by B. Russell). The result of this examination is (1) to show that Meinong's theory, though true in its intention, is seriously at fault in its practical conception of an *a priori* science of colour, because of the ignorance of its author of the principles of mathematics as revealed by recent researches of mathematicians, and (2) to necessitate a more exact discrimination between the standpoints of Empirical Psychology and Mathematical Science. In order to sustain his negative criticism of Meinong's "Geometry of Colours," the writer then endeavours to prove that the formal relations obtaining between colours are the very same as those with which mathematics is ordinarily conversant,

and to formulate a few provisional though fairly definite laws of a kind which colour-mathematics has to determine.

"A List of S.A. Fungi." By Miss A. M. BOTTOMLEY.

This paper is a systematic compilation, with indexes of all the South African Fungi in the Government Mycological Herbarium. It records some 276 genera and 800 named species, some of the more important or more interesting of which are illustrated by photographs of actual specimens.

Considerable space is occupied by the Rusts, the Perisporales and the Pore Fungi, three groups which are receiving particular attention in the Mycological Department.

ORDINARY MEETING.

An Ordinary Meeting was held on Wednesday, October 17th, 1917, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

Dr. A. JASPER ANDERSON, Vice-President, was in the Chair.

The Minutes of the previous Meeting were confirmed.

Mr. C. D. LESLIE and Mr. BERNARD PRICE were elected members of the Society.

Mr. L. P. BOSMAN, B.A., and Prof. R. W. WILCOCKS were nominated for membership.

The CHAIRMAN gave notice of the election of the Council, President and Officers, and announced the Council's recommendation to the Society as members of Council for 1918 of the following seven members of the existing Council:—A. JASPER ANDERSON, W. A. CALDECOTT, G. S. CORSTORPHINE, L. CRAWFORD, S. S. HOUGH, W. A. JOLLY, and L. PÉRINGUEY; and the following five Fellows:—J. C. BEATTIE, J. D. F. GILCHRIST, J. MOIR, I. B. POLE-EVANS, and Sir A. THEILER.

The Council further recommend J. D. F. GILCHRIST as President, L. CRAWFORD as Hon. Treasurer, and W. A. JOLLY as Hon. General Secretary.

COMMUNICATIONS:

"Spectrum phenomena in the Chromium Compounds: being Part IV of the spectrum of the Ruby and Emerald." By JAMES MOIR.

It has been found that although aqueous solutions of the chromium salts do not show any narrow characteristic bands in the spectrum, yet when anhydrous (or nearly anhydrous) solutions are used, the spectrum is crossed by narrow bands in the red similar to what are seen in the ruby or emerald spectrum.

The solutions of chromium oxide in conc. sulphuric and in fused metaphosphoric acid have been investigated and the bands measured; they are very similar to those seen in the emerald, but not absolutely identical;

whilst the bands of the ruby, although similar in arrangement, are displaced into a region of lower frequency. Both gem colours are due to chromium, but the vibrations are differently loaded (silica and beryllia against alumina).

"Colour and Chemical Constitution. Part III: Derivatives of the unknown ortho-para-phenolphthalein." By JAMES MOIR.

Phthaleins in which one of the hydroxyl-groups is *ortho*- and the other *para*- to the central carbon have been prepared from para-substituted phenols with oxybenzoylbenzoic acid. They are like the common phthaleins, but their absorption-bands are broad, although in much the same position. An attempt to make *o-p*-phenolphthalein itself gave a product very closely resembling common phenolphthalein, and a similar substance was obtained by dehydrating oxybenzoylbenzoic acid alone with sulphuric acid. They are, nevertheless, probably not identical with common phenolphthalein. "Phenolphthaleinoxime" is not an oxime, but is the *p*-oxyanil of oxybenzophenonecarboxylic acid. Common phenolphthalein in normal alkali is colourless when cold, but becomes pink on warming.

MINUTES OF PROCEEDINGS
OF THE
ROYAL SOCIETY OF SOUTH AFRICA.

ANNIVERSARY MEETING.

The Anniversary Meeting of the Society was held on Wednesday, March 20th, 1918, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

The President, Dr. L. PÉRINGUEY, was in the Chair.

The Report of the Hon. General Secretary was submitted and adopted.

The Report of the Hon. Treasurer was submitted and adopted.

The following were elected Members of Council for the year 1918:

Dr. A. JASPER ANDERSON. Mr. S. S. HOUGH.

Dr. J. C. BEATTIE. Dr. W. A. JOLLY.

Dr. W. A. CALDECOTT. Dr. J. MOIR.

Dr. G. S. CORSTORPHINE. Dr. L. PÉRINGUEY.

Dr. L. CRAWFORD. Mr. I. B. POLE-EVANS.

Dr. J. D. F. GILCHRIST. Sir A. THEILER.

Dr. J. D. F. GILCHRIST was elected President.

Dr. L. CRAWFORD, Hon. Treasurer.

Dr. W. A. JOLLY, Hon. General Secretary.

The President referred to the loss sustained by the Society through the death of the late Prof. P. D. Hahn, and spoke of his great services to the Society and to Science in South Africa.

REPORT OF THE HON. GENERAL SECRETARY FOR THE YEAR ENDING
DECEMBER 31, 1917.

Six Ordinary Meetings, the Annual Meeting and the Anniversary Meeting were held during the year, and the following papers were read:

"Note on Palmström's Generalisation of Lamé's Equation," by Sir THOMAS MUIR.

"*Mestoma antarcticum* from Bloemfontein (sp. nov.)," by T. F. DREYER.

"Colour and Chemical Constitution: A Study of the Phthaleins and Related Compounds," by JAMES MOIR.

"Note on the Expansion of the Product of Two Oblong Arrays," by Sir THOMAS MUIR.

"Notes on Radiation of Crystals," by J. STEPH. V. D. LINGEN.

"A Summary of the Distribution of the Genera of South African Flowering Plants (with Special Reference to the Flora of the Uitenhage and Port Elizabeth Divisions)," by S. SCHÖNLAND.

"Note upon the Endocranial Cast obtained from the Ancient Calvaria found at Boskop, Transvaal," by G. ELLIOT SMITH.

"Note on a Case of Hermaphroditism," by H. V. EXNER.

"Note on the Genus *Terfezia*: A Truffle from the Kalahari," by I. B. POLE-EVANS.

"Note on the Resolvability of the Minors of a Compound Determinant," by Sir THOMAS MUIR.

"Colour and Chemical Constitution. Part II: The Spectra of the Mixed Phthaleins and of the Sulphone-phthaleins," by JAMES MOIR.

"Kimberley Diamonds: Especially Cleavage Diamonds," by J. R. SUTTON.

"On the Phanerogamic Flora of the Divisions of Uitenhage and Port Elizabeth," by S. SCHÖNLAND.

"A Lunar Period in the Rates of Evaporation and Rainfall," by J. R. SUTTON.

"Note on the Abnormal Development of the Genital Organs of *Jasus Lalandii*," by W. VON BONDE.

"On the Colour-Octahedron as a Complexity: Being Suggestions towards a Mathematics of Colour," by G. H. MALAN.

"A Survey of the Scorpion Fauna of South Africa," by JOHN HEWITT.

"On *Rana fuscigula* and *R. angolensis*," by G. A. BOULENGER, LL.D., D.Sc., F.R.S.

"The Torsion Problem for Bodies of Revolution," by E. T. STEGMANN.

"A List of South African Fungi," by Miss A. M. BOTTOMLEY.

"Spectrum Phenomena in the Chromium Compounds: being Part IV of the Spectrum of the Ruby and Emerald," by JAMES MOIR.

"Colour and Chemical Constitution. Part III: Derivatives of the Unknown Ortho-para-phenolphthalein," by JAMES MOIR.

The Society has awarded, on the recommendation of the General Committee for Grants in Aid of Research, the following grants:

£100 to Prof. J. T. MORRISON, for Investigation of Earth-tides.

£40 to Mr. J. S. V. D. LINGEN, for continuation of Researches in Radiology.

£35 to Prof. M. RINDL, for Chemical Investigation of some Toxic and Medicinal South African Plants.

£35 to Prof. S. J. SHAND, for a study of the Alkaline Igneous Rocks of the Transvaal.

£32 10s. to Mr. K. H. BARNARD, for the Collection of Terrestrial and Fresh-water Crustacea in the Union.

£32 10s. to Prof. J. W. BEWS, for Research on the Plant Succession in the Grass Veld of South Africa.

£25 to Prof. GEO. POTTS, for a Botanical Survey in the Orange Free State.

A Catalogue of the publications available in the Society's Library is now published in a work prepared and printed for the Trustees of the Public Library, Cape Town, entitled 'Cape Peninsula List of Serials.' This is a Catalogue of the publications available in the principal Libraries of the Peninsula, and a copy is available for the use of anyone using the Library.

A number of volumes of the Proceedings and Transactions of the Zoological Society of London were kindly presented to the Society by Canon M. M. WOOD.

The sum of £10 having been voted for binding, a commencement has been made with the 'Proceedings of the Royal Society of London' (Sections A and B), forty volumes of which are now in the hands of the binder. It is hoped that an annual vote may be made to carry on the binding of the contents of the Library.

During the year it became necessary to remove the surplus stock of 'Transactions' of the Society (S.A. Phil. Soc. and Roy. Soc. of S.A.). The stock was therefore removed, packed in suitably sized packages, labelled, and placed on the top of the shelving occupied by the Society's Library in the S.A. College Library, this being the only available place.

Owing to the want of sufficient shelving certain publications in the Library have had to be merely stacked together, so as to save space, and this renders them not only untidy in appearance but less convenient for reference, and the time is at hand when, unless additional shelving is provided, some of the contents of the Library will have to be packed up and stored away to make room for the annual increase.

The matter of additional shelving has been brought forward annually since the Report for 1913, and the position now is that before the extra shelving can be erected a storeroom to accommodate over 200 packages of stock, in addition to stationery, etc., will have to be provided, as the extra shelving can only be erected on the top of the present shelving, there being no lateral space available.

Vol. V, Part 6, and Vol. VI, Parts 1, 3 and 4 of the Society's Transactions have been issued during the year. (Vol. VI, Part 2, will be issued early in 1918.) The exceptional delay in the publication of the papers

TREASURER'S ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1917.

| REVENUE. | | | | EXPENDITURE. | | | | | | |
|--|----|----|---|---------------------|----|----|---|------|----|---|
| £ | s. | d. | £ | s. | d. | £ | s. | d. | | |
| To Subscriptions received in 1917 : | | | | By Publications ... | | | | 315 | 13 | 9 |
| for 1915, 1 Fellow at £2 ... | | | | 2 | 0 | 0 | " Landing Charges, etc. ... | 3 | 19 | 1 |
| for 1916, 4 Fellows at £2, 7 Town Members at £2, 14 Country Members at £1 ... | | | | 36 | 0 | 0 | " Research Grants : ... | | | |
| for 1917, 42 Fellows at £2, balance 1 Fellow at £1 18s. 6d., 45 Town Members at £2, 84 Country Members at £1 ... | | | | 259 | 18 | 6 | Payment of Grants ... | 165 | 0 | 0 |
| for 1918, 1 Fellow at £2, 3 Country Members at £1, Part 1 Country Member at 2s. ... | | | | 5 | 2 | 0 | Expenses in Advertising ... | 5 | 1 | 9 |
| for 1919, part 1 Fellow at £1 ... | | | | 1 | 0 | 0 | " Cost of Stamps on retaining £800 for one year on Fixed Deposit at Standard Bank ... | 170 | 1 | 9 |
| Entrance Fees, to be put to Capital ... | | | | 304 | 0 | 6 | " Compilation for International Scientific Catalogue of Papers ... | 0 | 4 | 0 |
| " Life Membership Subscriptions, to be put to Capital ... | | | | 8 | 0 | 0 | " Clerical Assistance and Work in Library ... | 25 | 0 | 0 |
| " Sale of Publications to Government ... | | | | 15 | 0 | 0 | " Local Printing and Stationery ... | 55 | 0 | 0 |
| " Sales of Publications otherwise ... | | | | 15 | 14 | 2 | " Postages and Stationery ... | 29 | 10 | 6 |
| " Sales of extra Reprints of Papers ... | | | | 33 | 6 | 9 | " Postages and Petties ... | 33 | 4 | 2 |
| " Government Grant, 1917-8 ... | | | | 300 | 0 | 0 | " Bank Charges for Commissions, Ledger Fees, etc. ... | 3 | 3 | 9 |
| " Interest on Fixed Deposit at Standard Bank ... | | | | | | | Less Commissions paid by Members ... | 1 | 13 | 9 |
| " Interest on money formerly in Post Office Savings Bank, to date of closing account ... | | | | 32 | 0 | 0 | " Hire of Rooms for Meetings and Caretaker, 1917 ... | 1 | 10 | 0 |
| | | | | | | | " Insurance of Library, Premium 1917-8 ... | 5 | 15 | 6 |
| | | | | | | | " Purchase of Books for Library ... | 0 | 5 | 6 |
| | | | | | | | " Balance, being excess of Revenue over Expenditure ... | 2 | 10 | 0 |
| | | | | 16 | 15 | 11 | | 182 | 3 | 1 |
| | | | | | | | | £824 | 17 | 4 |

ASSETS AND LIABILITIES AS AT DECEMBER 31, 1917.

| ASSETS.* | | LIABILITIES. | |
|--|------------|--|------------|
| | £ s. d. | | £ s. d. |
| Money at Standard Bank on Fixed Deposit at 4½ per cent. | 800 0 0 | Subscriptions, whole or in part, received for 1918, 1919 ... | 6 2 0 |
| Money in Savings Bank Department of Standard Bank (Life Subscriptions and Entrance Fees) ... | 167 0 0 | Research Grants unpaid, whole or in part :— | |
| Union of S. Africa 5 per cent. Stock (1921-36) ... | 400 0 0 | Miss M. Wilman (1914) ... | 425 |
| Balance in Standard Bank, as per Pass Book ... | 109 19 7 | Prof. J. T. Morrison (1917) ... | 4100 |
| Arrears of Subscriptions, as in Statement for 1916, due at beginning of 1917, £76, less £37 paid in year and £26 struck off as irrecoverable ... | 13 0 0 | Prof. S. J. Shand (1917) ... | 435 |
| Arrears of Subscriptions for 1917 ... | 36 18 6 | Binding 'Proceedings of Royal Society of London' ... | 160 0 0 |
| | | Earmarked for Expense of Publishing, as a part of the 'Transactions,' a reproduction of a Bushman Painting (Council Minutes, May 12, 1915) a sum not exceeding ... | 9 0 0 |
| | | Balance from 1912 Conversazione carried forward towards the expenses of future Conversazione in Capetown ... | 350 0 0 |
| | | Capital at December 31st, 1917, being excess of Assets over Liabilities ... | 7 4 0 |
| | | | 994 12 1 |
| | £1526 18 1 | | £1526 18 1 |

Minutes of Proceedings.

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Exclusive of value of Library and Publications of the Society held in stock.*

We hereby certify that we have examined the above balance and revenue account with the books, vouchers and Banker's pass book relating thereto, and that in our opinion they correctly set forth a true and correct statement of the affairs of the Society.

J. HALM
CHAS. F. JURITZ.

NOTE.—Accounts for some printing ordered in 1917 have not yet been received.

contained in these parts was quite unavoidable, owing to accidents at the printing works, on two occasions, and to the difficulty of obtaining material.

The number of Honorary Fellows is 3; Fellows 50; Members 165.

The Society regrets to have to record the death, since the 1916 Anniversary Meeting, of Prof. P. D. Hahn, Fellow, Dr. H. Becker, Mr. D. J. Haarhoff, Life Member, Mr. A. G. Howitt, M.C., Member on military service, Mr. S. Mendelssohn, Member, and Mr. W. Wardlaw Thompson, Member. Mr. E. Jacot, Member on military service, has been reported missing.

The Society desires to record that Lieut. L. H. Walsh, Member on military service, has been awarded the Military Cross in addition to the D.C.M. gained in 1916.

A resolution was passed by the Society that the subscriptions of a Member on active or national service be remitted for the time of his absence from the Union of South Africa, and that the parts of 'Transactions' published during his absence be sent to him without charge when he returns to civilian life; provided that he intimates his intention to resume membership of the Society.

WM. A. JOLLY,

Hon. General Secretary.

ORDINARY MEETING.

An Ordinary Meeting was held after the Anniversary Meeting.

The President, Dr. J. D. F. GILCHRIST, was in the Chair.

The Minutes of the last Ordinary Meeting were confirmed.

Prof. R. W. WILCOCKS and Mr. L. P. BOSMAN were elected Members of the Society.

The following were nominated for Membership:—Mr. R. W. E. TUCKER, Mr. G. A. H. BEDFORD, Dr. MELLE, Mr. P. v. d. RIET COPEMAN and Mr. W. J. COPENHAGEN.

Mr. A. L. HALL was received as a Fellow.

ORDINARY MEETING.

An Ordinary Meeting was held on Wednesday, April 17th, 1918, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

The President, Dr. J. D. F. GILCHRIST, was in the Chair.

BUSINESS:

The Minutes of the previous meeting were confirmed.

Mr. R. W. E. TUCKER, Mr. G. A. H. BEDFORD, Dr. MELLE, Mr. P. v. d.

RIET COPEMAN and Mr. W. J. COPENHAGEN were elected Members of the Society.

Dr. M. R. DRENNAN, proposed by Dr. J. D. F. GILCHEIST, seconded by the Hon. SECRETARY, and—

Dr. CORNELIS PIJPER, proposed by Miss M. WILMAN, seconded by Mr. J. R. SUTTON, were nominated for membership.

Sir A. THEILER and Dr. J. MOIR were received as Fellows.

COMMUNICATIONS:

"Luminosity in a South African Earthworm and its Origin." By J. D. F. GILCHEIST.

Luminous earthworms are found on the slopes of Table Mountain. The luminosity proceeds from a discharge from the mouth and anus which consists of cells heavily laden with inclusions of different kinds. The smaller inclusions consist of a substance allied to fat, by the oxidation of which the light is produced. The cells arise from the body-cavity and are discharged into the anterior and posterior parts of the alimentary canal by definite communications between the coelom and alimentary tract.

"Note on the Adjugate of Bezout's Eliminant of Two Binary Quantics." By Sir THOMAS MUIR.

"On the Genera *Diplocystis* and *Broomeia*." By I. B. POLE-EVANS and AVERIL M. BOTTOMLEY.

Some specimens of *Diplocystis* have recently been obtained by the authors from Portuguese East Africa, and this is the first recorded occurrence of this interesting genus from Africa. The African material is not identical with that from Cuba, and the authors describe it as *Diplocystis junodii* nov. spec.

"South African Perisporiaceae. II: Revisional Notes." By ETHEL M. DOIDGE.

This communication consists of a revision, due to work on a number of fresh collections of South African Perisporiaceae, of a previous communication on the subject by the author.

"Fresh-water Snails as a Cause of Parasitic Diseases." By F. G. CAWSTON.

The author describes a number of snails collected by him from various districts in South Africa, and found to be infested with the cercarial stages of the various trematode worms.

"Colour and Chemical Constitution. Part IV: The Remaining Phthaleins." By JAMES MOIR.

The absorption-spectra of complex phthaleins are described, these being partly duplex compounds of the phenol-anthrol type and partly of a new class (e.g. thymol-naphthol) derived from thymoylbenzoic acid. The additive nature of the effects of different substitutions is emphasised by means of a table giving the numerical values of the change of wave-length for different substituting groups.

ORDINARY MEETING.

An Ordinary Meeting was held on Wednesday, May 15th, 1918, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

The President, Dr. J. D. F. GILCHRIST, was in the Chair.

BUSINESS:

The Minutes of the previous meeting were confirmed.

Dr. M. R. DRENNAN and Dr. CORNELIS PIJPER were elected Members of the Society.

Mr. G. J. HARKINS, proposed by Dr. L. PÉRINGUEY, seconded by the HON. SECRETARY, and Dr. L. J. KRIGE, proposed by Mr. J. S. v. d. LINGEN, seconded by the HON. SECRETARY, were nominated for Membership.

Mr. C. W. MALLY was received by the PRESIDENT as a Fellow of the Society.

The HON. SECRETARY announced the names of the following members who are candidates for Fellowship:

ALEXANDER BROWN, proposed by J. C. BEATTIE, J. T. MORRISON, H. BOHLE, A. OGG.

MISS ETHEL MARY DOIDGE, proposed by A. W. ROGERS, A. L. HALL, I. B. POLE-EVANS, J. C. BEATTIE.

HAROLD BENJAMIN FANTHAM, proposed by J. C. BEATTIE, E. T. MELLOR, I. B. POLE-EVANS, A. W. ROGERS.

SYDNEY H. HAUGHTON, proposed by A. W. ROGERS, R. B. YOUNG, A. L. HALL, C. F. JURITZ, J. D. F. GILCHRIST.

ANDREW YOUNG, proposed by P. A. WAGNER, A. L. DU TOIT, R. B. YOUNG, C. F. JURITZ.

The PRESIDENT announced his nomination of Dr. A. JASPER ANDERSON and Dr. G. S. CORSTORPHINE as Vice-Presidents.

COMMUNICATIONS:

"South African Perisporiaceae. III: Notes on Four Species of *Meliola* hitherto unrecorded from South Africa." By ETHEL M. DOIDGE.

The fungi considered in the paper are all from Natal and the eastern part of the Cape Province, and have been identified from recent collections.

"Reproduction of Fishes in Table Bay." By J. D. F. GILCHRIST.

The eggs and young of 21 species of fishes were procured in about 60 tow-nettings made at more or less regular intervals throughout the year. Fourteen of these were referred to known species. The eggs procured and larvae hatched from them are described and figured. The eggs of the Sardine (*Sardina sagax*) and of the Anchovy (*Engraulis capensis*) indicate that these fish are present in abundance, though as yet not utilised for economic purposes.

"Note on the Electrogram of the Medulla oblongata." By W. A. JOLLY.

ORDINARY MEETING.

An Ordinary Meeting was held on Wednesday, June 19th, 1918, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

The President, Dr. J. D. F. GILCHRIST, was in the Chair.

BUSINESS:

The minutes of the previous meeting were confirmed.

Mr. G. J. HARKINS and Dr. L. J. KRIGE were elected members of the Society.

Prof. W. B. M. MARTIN, M.D., Prof. T. J. MACKIE, M.D., and Dr. E. S. COGAN were nominated for membership.

EXHIBITIONS:

Mr. S. H. HAUGHTON exhibited two skulls of a new form of Carnivorous Therapsid (Reptilia) from the Lower Beaufort Beds. The relationships with the known families, and the differences from them, were discussed, and the form—for which the name *Whaitsia platycops* was proposed—was shown to belong to a new family, which may be called the *Whaitsiidae*.

Dr. L. PÉRINGUEY exhibited some Bushman paintings on stones, found in the cave shelters of Plettenberg Bay, and mostly executed in black, black and white, and red ochre. Hitherto only parietal, *i. e.* paintings on walls or roofs of shelters, have been recorded. In the present instances, however, the paintings are on flat detached fragments of quartzite, some thin, others thicker; occasionally there is a convex one, and in some cases the continuation of the painting is to be observed on the cleft or side part; the blocks sometimes bear paintings on both faces. The subjects are animals, rendered with the well-known accuracy of the San; and human, somewhat conventional figures, running, dancing, struggling, etc. The technique is that obtaining in the Lange Kloof (George), but one of these paintings represents men with tattoo-marks, bearded, and with either tousled hair or head-dresses, reminding one of the attitude and appearance of the Lybians decorating the tomb of the Egyptian King Seti the First and other Egyptian delineations.

We now know that some such paintings were used by the Strand Loopers as a kind of votive offering and placed over the tucked-up body in rock-shelters of the littoral, filled almost to the roof with broken and partly pulverised shells, *débris de cuisine*, etc. Some of these shelters are partially filled with stalactite columns formed after the filling of the cave, because the stalagmite rests on the *débris*, and it is under the edge of such a column that one of the paintings was found. This fact postulates a certain antiquity, the more so that the soil from which the stalactite formation is derived is very poor in lime.

Judging from the relics of their industry as revealed in these sepultures, the Strand Loopers were in the age of stone and bone combined, and their

technique is of the most primitive kind, as revealed by the implements and tools exhibited.

The art of painting, more than the difference in language, divides the Hottentot from the Bushman. The former (Khoi Khoi) does not paint; the Bushman (San) does. The Hottentot is a comparatively late comer, for the Bushman has never reproduced, except quite lately, the long-horned ox and the fat-tailed sheep, which the Khoi Khory brought with him to South Africa.

COMMUNICATIONS:

"A Note on the Possibility of Long-Range Weather Forecasts." By J. R. SUTTON.

The author shows that the June temperatures, and especially the minima, at Kimberley are modified by the character of the May rainfall.

"South African Perisporiaceae. IV: New Species from the Coast Districts."

Nine new species are described of fungi belonging to the Perisporiaceae; of these six belong to the genus *Meliola*, two to the genus *Zukalia*, and one to the genus *Phaeodimeriella*; these were all collected in different localities near the coast in the Cape Province, Natal, Zululand and Portuguese East Africa.

"Preliminary Note on Anatase." By J. S. v. D. LINGEN and A. R. E. WALKER.

The authors gave a preliminary account of their investigations on the radiation pattern of Anatase.

ORDINARY MEETING.

An Ordinary Meeting was held on Wednesday, July 17th, 1918, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

Dr. A. JASPER ANDERSON, Vice-President, was in the chair.

BUSINESS.

The Minutes of the previous meeting were confirmed.

The Society, on the motion of the Vice-President, recorded its profound sympathy with Mr. S. S. Hough on the death of Mrs. Hough, and its sense of the deep loss which the community has sustained in the loss of one who took so active a part in its life.

Prof. W. B. M. MARTIN, Prof. T. J. MACKIE and Dr. E. S. COGAN were elected Members.

Dr. E. R. MONTGOMERY and Mr. W. F. SCHLUPP were nominated for Membership.

COMMUNICATIONS.

"On the Electrostatic Deflection in a Cathode Ray-tube." By A. OGG, F.R.S.S.Af.

In the ordinary Thomson cathode ray-tube for determining the value of e/m for cathode rays we have to allow for the irregularity of the electrostatic field near the edges of the charged plates. It is interesting to find the electrostatic deflection when the rays are projected parallel to the plates, but at some distance from them. The author gives methods for making the calculation.

"Note on a Disease in the Snoek (*Thyrskites atun*)." By J. D. F. GILCHRIST, P.R.S.S.Af.

The snoek, one of the most important Cape fishes from an economic point of view, is well known to be found frequently in a "pap" or soft condition. This is attributed by the fishermen to the fact that it has not been properly killed on capture, the consequence being that it struggles about in the bottom of the boat, and, in doing so, bruises the flesh to such an extent as to produce the condition mentioned. This condition may occur a few hours after the fish has been caught, and may quickly become so marked that the whole of the muscles, especially of the back, appear quite soft and liquid. The process is believed to be totally distinct from decay by putrefaction or by softening of the flesh by exposure to the heat of the sun, which also frequently occurs. As it was suspected that this condition might be brought about by the presence and rapid multiplication of some Protozoal parasite in the muscles, the diseased tissue was examined microscopically, and after staining with methylene-blue and other reagents the presence of very numerous spore-like bodies was detected. These were all arranged in groups of fours, and occasionally, on fixation by heat, long filaments were shot out from them, showing that they were Protozoa belonging to the group of Cnidosporidia, which are known to produce diseased conditions in the muscular and other tissue of fish. The groups of four bodies with filaments suggest the family of the Chloromyxidae with their four polar capsules, but there is reason for believing that they represent spores, not polar capsules, and if so they probably belong to a new form of the Microsporidia.

"Mycological Notes. I." By Miss ETHEL M. DOIDGE.

ORDINARY MEETING.

An Ordinary Meeting was held on Wednesday, August 21st, 1918, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

The President, Dr. J. D. F. GILCHRIST, was in the Chair.

BUSINESS:

The minutes of the previous meeting were confirmed.

Dr. E. R. MONTGOMERY and Mr. W. F. SCHLUPP were elected Members.

Dr. W. E. DE KORTE and Prof. G. H. STANLEY were nominated for Membership.

COMMUNICATIONS:

"On the Velocities of two Distinct Groups of Secondary Corpuscular Rays Produced by a Homogeneous Röntgen Radiation and their Absorption Co-efficients in Gases." By LEWIS SIMONS.

The absorption co-efficients in gases of the secondary corpuscular rays produced by the incidence of silver X-rays on a single gold leaf were found by calculation from the pressure at which the cathode ionisation falls to half its maximum value. They are probably too high for the fastest corpuscles produced.

The log. cathode ionisation curves could be analysed into two distinct portions when the particles emerge from a very thin screen, giving two absorption co-efficients in a gas, their ratio being 1 : 4.76.

The maximum velocity of emergence of the slower corpuscle was calculated from

$$\frac{1}{2}mv^2 = n_a h\nu_k - (n_b h\nu_i + h\nu_u + \text{etc.}),$$

which gives a value 65×10^8 cm./sec., and therefore since $h\nu^4 = \text{const.}$, the velocity of the faster corpuscle = 96×10^8 cm./sec. The mean value of the velocity of the parent cathode particle producing silver X-rays calculated from the results of Rutherford, Barnes and Richardson and from Duane and Hunt and from $\frac{1}{2}mv^2 = n_a h\nu_k$ is 96.5×10^8 cm./sec.

"On a New Lizard of the Genus *Latastia* from Southern Rhodesia." By G. A. BOULENGER.

"On *Rana ornatissima* and *Rani ruddi*." By G. A. BOULENGER.

"On a Nematode of Fowls having a Termite as an Intermediate Host." By Sir A. THEILER.

Some time ago a farmer forwarded a species of Termites infected with a nematode, inquiring whether these worms were a stage in the life-cycle of the wire-worm of sheep (*Haemonchus contortus*). This possibility, of course, had to be excluded, but since they were larvae, it was concluded that they represented a stage in the life-cycle of a nematode, which had its habitat in a host that would consume termites. Many birds are known to eat termites; fowls are particularly fond of them. It was decided to feed infected termites as well as the larvae extracted from them. For this purpose eggs were hatched in an incubator and the chickens reared under conditions excluding accidental infection. Infected termites were found on red soil in the neighbourhood of a kaffir kraal. A series of experiments were carried out, and in every instance an imago was so obtained in the small intestines of the fowls.

The control fowls were free of it, as well as controls running in an area not inhabited by the species of termites. The imago was identified as a *Filaria* and since it turned out to be a new species, the name *Filaria gallinarum* is proposed. According to Maupas, free-living nematodes undergo four different ecdyses to reach the mature stage. This applies also to the half parasitic nematodes (e.g. *Ankylostoma duodenale*, *Haemonchus contortus*, *Trichostrongylus douglasii*). These stages could not be definitely traced in the cycle of *Filaria gallinarum*. The first ecdysis was found in the termite. The second ecdysis does not take place there, as could be expected. Two stages were found in the fowl. It is thus possible that only three ecdyses are present, the second one being suppressed, not being necessary as in the case of half parasitic nematodes, in which the larva, after having undergone the second ecdysis, is enclosed in a skin that protects it against external influences until it has been picked up by the host. The infected termite is known as the houtkopper, and was identified by Fuller as *Hodotermes pretoriensis*. It is of interest to note that only workers are infected, thus supporting the view that the food of the two types of termites is different.

"Note on Recurrents Resolvable into a Sequence of Odd Integers." By Sir THOMAS MUIR.

"Meliolaster: A New Genus of the Microthyriaceae." By Miss E. M. DOIDGE.

A fungus, occurring on *Piper capensis*, is described, which combines certain characters of the genera *Meliola* and *Asterina*.

ANNUAL MEETING.

The Annual Meeting was held on Wednesday, September 25th, 1918, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

The President, Dr. J. D. F. GILCHRIST, was in the Chair.

The following were elected Fellows of the Society:

ALEXANDER BROWN, M.A., B.Sc., proposed by J. C. BEATTIE, J. T. MORRISON, H. BOHLE and A. OGG.

ETHEL MARY DOIDGE, M.A., D.Sc., proposed by ARTHUR W. ROGERS, A. L. HALL, I. B. POLE-EVANS and J. C. BEATTIE.

SIDNEY H. HAUGHTON, B.A., proposed by ARTHUR W. ROGERS, ROBERT B. YOUNG, A. L. HALL, CHAS. F. JURITZ and J. D. F. GILCHRIST.

HAROLD BENJAMIN FANTHAM, M.A., D.Sc., proposed by J. C. BEATTIE, EDW. T. MELLOR, I. B. POLE-EVANS and ARTHUR W. ROGERS.

ANDREW YOUNG, M.A., D.Sc., proposed by PERCY A. WAGNER, ALEX. L. DU TOIT, ROBERT B. YOUNG and CHAS. F. JURITZ.

ORDINARY MEETING.

An Ordinary Meeting (postponed on account of the epidemic prevailing at the time) was held on Wednesday, October 30th, 1918, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Capetown.

The President, Dr. J. D. F. GILCHRIST, was in the Chair.

BUSINESS:

The Minutes of the previous meeting were confirmed.

Dr. W. E. de KORTE and Prof. G. H. STANLEY were elected Members.

Prof. D. THODAY was proposed for membership by the Hon. Treasurer, seconded by the Hon. General Secretary.

The Chairman gave notice of the election of the Council, President and Officers, and announced the Council's recommendation to the Society as Members of the Council for 1919 of the following seven Members of the existing Council: J. C. BEATTIE, L. CRAWFORD, J. D. F. GILCHRIST, W. A. JOLLY, J. MOIR, I. B. POLE-EVANS and Sir ARNOLD THEILER; with the following five additional Fellows: C. W. MALLY, J. T. MORRISON, C. E. MOSS, A. OGG and G. ROBERTSON.

The Council further recommend J. D. F. GILCHRIST as President, L. CRAWFORD as Hon. Treasurer, and W. A. JOLLY as Hon. General Secretary.

COMMUNICATIONS:

"Haemolysis by Serum in Combination with certain Benzol Bodies."

By T. J. MACKIE.

It has been shown that while serum-complement acts as haemolysin in the presence of a specific immune body, and also along with colloidal sicilic acid, serum is also capable of producing lysis of red blood-corpuscles which have been treated with certain benzol bodies. The paper records the result of experiments carried out with brilliant green.

"A Possible Lunar Influence upon the Velocity of the Wind at Kimberley." By J. R. SUTTON.

The object of this paper is to discuss the question whether there is a lunar term in the velocity of the wind at Kimberley. The results of hourly observations made during 180 lunations reveal only one definite maximum and minimum of velocity in the lunar curve, the former falling about three hours before lunar midnight, the latter just before lunar noon, the range being 20 miles an hour. When the moon is in south declination, the maximum of velocity is near lunar noon and the minimum near lunar midnight, the opposite being the case when the moon is north, the

respective ranges of velocity being .32 and .55 miles an hour, which are greater than one would have expected to find.

"South African Perisporiaceae. V: Notes on an Interesting Collection from Natal." Miss ETHEL M. DOIDGE.

A number of leaf fungi are described from Natal, chiefly belonging to the genus *Meliola*, and including hitherto undescribed species.

"Fusion of Karroo Grits in Contact with Dolerite Intrusions." By ANDREW YOUNG.

Certain unusual contact alterations occurring in the Heilbron district were described. Dolerite intrusions have apparently fused the Karroo sandstone or grit to a dark glass resembling pitchstone. The contacts are sharply defined, and the vitrification extends to a distance of several yards from the actual contact plane. The results of a detailed petrological examination of the dolerite, the glass, and the sandstone were described. The dolerite presents no abnormal features. The sandstone contains much soda felspar. The glass on analysis yields about 7 per cent. of soda and about 5 per cent. of combined water. The glass might thus be called a pitchstone. Microscopic examination of the glass shows the presence of microlites of cordierite, magnetite, and also a fibrous mineral with physical properties suggestive of an amphibole. These microlites seem to be practically identical with those described by Harker and Clough as occurring under somewhat similar circumstances in the island of Soay near Skye.

"On Hyalite." By J. S. v. d. LINGEN and A. R. E. WALKER.

The points of resemblance between hyalite and liquid spherulites are noted. The truth of the statement that liquid spherulites and—under certain conditions—hyalite, give uniaxial figures when examined in convergent polarised light is questioned.

"On Anatase." By J. S. v. d. LINGEN and A. R. E. WALKER.

The authors exhibited a Laue radiograph of Anatase which shows that, according to the usual interpretation of such a photograph, the mineral possesses full tetragonal symmetry.

Herbert Smith and W. von Bonde have, independently, suggested that possibly it did not possess the full degree of symmetry usually assigned to it; in both cases this suggestion was based on a study of the external crystal form of the mineral.

"On Radioactive and Other Minerals Associated with Fossil Wood from the Beaufort Series." By A. R. E. WALKER.

A description is given of torbernite and a mineral allied to uranocircite occurring, associated with calcite and barytes, encrusting and impregnating fossil wood from beds of Lower Beaufort age on the farm Quaggasfontein.

"On Tantalite Crystals from Namaqualand." By A. R. E. WALKER.

A description is given of a number of crystals obtained from a tantalite prospect at Jakals Water, Namaqualand.

The collection represents specimens, which, solely because they possessed crystal faces, were set aside during the sorting of tantalite from *débris* obtained by blasting.

Apparently two distinct varieties of tantalite are represented which, whilst exhibiting a general similarity of crystal form, consistently differ from each other in certain crystallographic details, in specific gravity and other physical characters, and presumably in chemical composition.

Attention is drawn to the fact that if the form *n* (133) occurring on the crystals of tantalite be regarded as the unit pyramid (111), this would accordingly necessitate turning the crystals round their vertical axes through 90 degrees in order to read them correctly as orthorhombic crystals.

If that be done the crystals of tantalite exhibit not only a very close resemblance in form and habit to the figured crystals of polycrase and euxenite, but the crystallographic angles also approximate very closely to those recorded for both polycrase and euxenite.

Polycrase and euxenite are niotates and titanates of yttrium, erbium, cerium and uranium, and it is suggested that they may be isomorphous with tantalite, and that the intergrowth of very minute quantities of these minerals with the tantalite may account for the radioactivity of the latter mineral.

"Colour and Chemical Constitution. Part V: The Yellowness of Certain Phthaleins when Acid." By JAMES MOIR.

Phenolsulphonephthalein, on account of its high ionisation, does not form a colourless ring-lactone like phenolphthalein, but remains yellow when acidified: it is really the orthosulphonic acid of benzaurine (which shows similar colour changes). Benzaurine parasulphonic acid and benzaurine-carboxylic methylester ("phenolphthalein methylester") have now been made and found to possess the same property of yellowness in acid solution, lactone-formation being excluded in both cases. The latter substance is coloured pink by bicarbonates, and not bleached by excess alkali.

"Colour and Chemical Constitution. Part VI: The Ultra-violet Spectra of the Phthaleins." By JAMES MOIR.

A discussion of Howe and Gibson's discovery of violet and ultra-violet absorption-bands in alkaline phthaleins. These have frequencies which are $1\frac{1}{4}$ times and twice those of the visible band. It follows that the fundamental vibration of alkaline phenolphthalein is still unobserved, being in the infra-red at λ 11090 (frequency 9.02) on the usual scale. The visible band in the green is its 1st harmonic, and the other two are its 2nd and 3rd. The bands of phthaleins in H_2SO_4 solution described in Part I (1917) are due to the violet 2nd harmonic "loaded" with H_2SO_4 and so brought up into the green. Similar "loading" effects are observable in other heavy solvents. If y is the visible H_2SO_4 frequency, and x is the violet alkali frequency, then

the law $y = x - 7$ holds for all the phthaleins, the constant 7 representing the molecular volume of H_2SO_4 .

"Colour and Chemical Constitution. Part VII: Inorganic Phenomena in Connection with Cobalt, Nickel, Manganese and Uranium." By JAMES MOIR.

"Colour and Chemical Constitution. Part VIII: Fluorescence and its Laws." By JAMES MOIR.

On comparison of the spectra of dissolved (ionised) salts of these metals with those of the salts in the solid state, "loading" effects are observed similar to those shown by the phthaleins. The formation of blue cobalt compounds is ascribed to considerable increase of molecular weight due to combination with environing molecules. In the case of cobalt halides the wave-lengths appear to be proportional to the eighth root of the molecular weight, and in uranyl compounds they are proportional to the sixth root. The coincidence of these numbers with the periodic place of the element is noted.

Solid uranyl compounds fluoresce, and the emission-spectrum shows 4 or 5 bands which are the absorption-bands of the same substances moved up from the blue into the green. The general law $\lambda_1 = 0.145 \lambda^{\frac{1}{3}}$ expresses the change of wave-length from absorption to fluorescence-emission; thus an absorption-band at λ 499 in any of these solid fluorescent substances is accompanied by a fluorescent band at λ 574, which agrees with the above formula. This relationship between cube of fluorescent wave-length and fourth-power of absorption wave-length appears to hold for other fluorescent substances as well as for uranium compounds.

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REPRODUCTION OF FISHES IN TABLE BAY.

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(With Plates I and II.)

The following account of the reproduction of fishes in Table Bay is based on material collected by tow-netting throughout the period of one year. Many eggs of fishes of various kinds were procured and hatched out to their free larval stage. The character of eggs and larvae are described, and, as far as possible, identified, and the times and relative abundance of spawning are noted. A few tow-nettings were also carried out at Knysna and contained fish eggs, and the eggs of some fish procured from mature females were also obtained and these are included.

Some of the results of this work have been somewhat unexpected, as, for instance, the presence of large quantities of the eggs of the Anchovy (*Engraulis capensis*) in Table Bay, a fish which is not well known to the Cape fishermen. The eggs were found towards the end of September and again in January, so that the spawning period is evidently in the summer months. The eggs of the Sardine (*Sardina sagax*) were found in quantity in September. The eggs of the Maasbanker were found in fair abundance in August and a few in September, and this appears also to be the spawning time of the Sole (*Synaptura microlepis*). The eggs of the White Stumpnose (*Chrysophrys globiceps*) were found chiefly from August to March. The most abundant of all were the eggs of a small fish, so little known that it has no local name. This fish belongs to the genus *Onos* (*Motella*). Its eggs were abundant throughout the whole period. Another fish (*Agriopus*, the "Horse Fish") seems also to spawn throughout the year. The eggs were found in abundance on the surface, but sometimes at some depth. These were the only submerged eggs procured, and their occurrence at some distance from the surface is probably due to their relatively large size and heaviness. The eggs of the Stockfish were not procured in abundance. The spawning period seems to be from July to October.

The following is a list of the species dealt with:

SPARIDAE.

1. *Chrysophrys globiceps*, C. & V.

TRIGLIDAE.

2. *Trigla kumu*, Less.
3. *Agriopus spinifer*, Smith.

CARANGIDAE.

4. *Caranx trachurus*, Lacep.

SCOMBRIDAE.

5. *Scomber colias*, Gmel.

Gobiidae.

6. *Gobius*, sp.

ATHERINIDAE.

7. *Atherina breviceps*, C. & V.

GADIDAE.

8. *Merluccius capensis*, Pappe.
9. *Onos capensis*, Kaup.

PLEURONECTIDAE.

10. *Synaptura microlepis*, Blkr.
11. *Arnoglossus capensis*, Blgr.

SCOMBRESOCIDAE.

12. *Hemirhamphus calabaricus*, Gthr.

CLUPEIDAE.

13. *Sardina sagax*, Jenyns.
14. *Engraulis capensis*, Gilch.

UNKNOWN SPECIES.

15. Species VIII.
16. " XVIII.
17. " XXIII.
18. " XXIV.
19. " XXV.
20. " XXVI.
21. " ?

SPARIDAE.

Chrysophrys globiceps, C. & V.

This fish is commoner in the waters of False Bay than in Table Bay, but the eggs were found in fair abundance in the latter locality. Two were found on August 16, and one or two occasionally up to October, when many more were found. From this time up to January they were abundant, though an occasional one was found up to the end of April.

The larvae of some of the eggs were reared to the sixth day after hatching.

TRIGLIDAE.

Trigla kumu, Less. (Pl. I, figs. 1 and 2; Pl. I, fig. 3.)

The eggs of the Red Gurnard were obtained from the end of August to the end of December, being most abundant in October. The egg and larvae are readily recognised, and are not very different from those of the common Gurnard of the northern hemisphere.

The eggs and larvae of this fish have already been described ('Mar. Inv.', vol. ii, p. 190, Pl. I, fig. 14). Those procured in Table Bay show that the egg varies in diameter from 1.25 mm. to 1.05 mm., those previously procured in False Bay from the living fish having been recorded as from 1.21 to 1.07 mm. The oil-globule varied from .24 to .23 mm., those from the living fish being uniformly .23 mm. In the Table Bay specimens it was noted that the oil-globule was of a yellow colour with dark margin. This yellow colour was not noted in the original description, but there can be little doubt from the characteristics of the egg and particularly of the larva that this is the Gurnard. The colour of the oil-globule has been found to vary or be entirely absent in European Gurnards. The larva from the Table Bay eggs was reared to a later stage than those of the False Bay eggs and has a dark pigmented border to the large pectoral fins. The length of the newly-hatched larva was 3.3 mm.

The original description of the egg and larva of *Trigla kumu* was written in 1904, and it is of interest to compare it with a subsequent account of the egg and larva of what appears to be the same species in New Zealand (Anderton in 'Trans. New Zealand Institute,' vol. xxxix, p. 478, 1907). The egg of the New Zealand *Trigla kumu* is given as 1.7 mm. in diameter; there is a single "large" oil-globule, which, calculated from the dimensions in the figures, appears to vary from about .22 to .18 mm.; this oil-globule was of a bright orange colour. The egg of the Cape Gurnard, therefore, is .45 mm. smaller than that of the New Zealand species, and the oil-globule, though about the same size, has less marked colour.

The larvae in both cases have similar markings, consisting of black and yellow chromatophores, which extend on to the fins. The size of the larva of the New Zealand Gurnard is, like that of the egg, somewhat greater than that of the Cape species, being about 4 mm. as against 3.31 mm.

These differences, however, are not very much greater than have been observed in the case of the European *Trigla gurnardus*, whose eggs have been found to vary from 1.63 to 1.16 mm. in diameter and the newly-hatched larva from 3 to 4 mm. in length.

Agriopus spinifer, Smith. (Pl. I, fig. 4; Pl. II, fig. 5.)

One of the most unexpected results of the tow-nettings in Table Bay was the great number of large eggs, which correspond in size and other characteristics to those already described as belonging to *Agriopus spinifer*. They

were found in almost every tow-netting throughout the whole period, and often in great abundance, yet the fish itself is not a common one. It does not, however, readily take the bait, and may be abundant in certain rocky localities, where it cannot be captured by the trawl, so that it may occur in greater abundance than is apparent. It was found occasionally in the trawling work of the "Pieter Faure," and the ripe eggs were procured and fertilised. These did not hatch out naturally, however, and the only information about the larva was obtained by dissecting out a well-advanced embryo from the egg. These eggs were 1.83 to 1.74 mm. in diameter. Dark stellate pigment-cells were found on the yolk and body, and the pectoral fin had a characteristic border of pigment just within its margin. The eggs procured in Table Bay, and believed to be those of *Agriopus*, were 1.88 to 1.71 mm. in diameter, and large, dark stellate spots appeared on the surface of the yolk at an early stage, as in the "Pieter Faure" specimens. Of a large number of eggs kept in water only a few hatched out, and that after a period of seven to eight days. The newly-hatched larva is very similar to that already described. It is 4 mm. in length and the dark border of the pectoral fin has a few reddish spots. There is some dark pigment at the rectum, and a fainter patch on the upper and under-surface of the body between the rectum and the posterior end.

The later larva is large, being 6.21 mm. in length, and its chief characteristic is its pectoral fins, which are large and fan-shaped and strikingly pigmented on the borders, the under-surface being of a dark colour, consisting of a number of black dots, while the upper surface of this region was of a striking red colour, consisting of reddish dots amongst which were a few dark dots. Over the rectum is a mass of black pigment-cells, and, posterior to this, another mass on each side of the body. Over the yolk are scattered large black stellate spots. The notochord is multicolumnar, and the rectum is not far removed from the yolk, though not close up to it. Fig. 5, drawn from life by Mr. H. A. T. Hunter, shows the general arrangement of the pigment.

CARANGIDÆ.

Caranx trachurus, Lacep.

This fish is common in and near Table Bay, but its eggs were not procured in abundance, and then only in the month of August. The eggs and larvae have already been sufficiently described. The fish is one of the few which seem to be quite identical with one in the northern hemisphere, and its early stages seem to be quite similar to those of the European species.

SCOMBRIDÆ.

Scomber colias, Gmel. (Pl. I, fig. 6; Pl. II, fig. 7.)

Certain eggs were procured in July in fair abundance, and again in August and October, but in fewer numbers. They vary in diameter from

1.15 to 1.05 mm., and contain a single oil-globule, the diameter of which varies from .23 to .21 mm. In the early stages, when the embryo is about half the circumference of the egg, the oil-globule is pink in colour with black stellate spots on it, and round it, in the yolk, are numerous yellow dots; these, as the embryo develops, appear to extend on to the oil-globule and the pink colour changes to pale grey. Yellow pigment-cells are scattered over the head region, behind the otocyst, and between the oil-globule and end of tail, and black branching cells are dispersed about the dorsal region of the embryo.

The larvae measure from 2.87 to 2.64 mm. in length. They had black branching spots on the dorsal region from head to about half-way between anus and end of tail, and on the oil-globule, which is in a posterior position. A mass of pigment cells are situated before and behind the eyes, and other masses between the rectum and the posterior end of yolk, and about midway between these and the end of the tail. The notochord is multi-columnar, the rectum anterior, and the yolk is homogeneous.

The animals were kept alive for seven days. On the third day the length had increased to 3.13 mm., and the oil-globule had darkened near its margin. On the seventh day the coloured pigment had spread considerably, and most of the black cells had disappeared. The pectoral fins were then apparent, and the anterior portion of the yolk-sac had assumed a brownish tint.

The egg and larva resemble so much those of the European mackerel (*Scomber scombrus*) that there is reason for believing that they belong to the South African *S. colias*.

Gobiidae.

Gobius sp. (Pl. I, fig. 8.)

The eggs of *Gobius nudiceps*, which is common in the Cape seas, have already been described from specimens deposited in the tanks of the marine laboratory at St. James. The eggs of another species were similarly found, and show a striking difference. They were deposited on the glass of the tank and could readily be examined. They were almost spherical in shape, one end however being somewhat tapering. They measured .96 by .73 mm. They were of a bright lemon-yellow colour, identical with that of the bands of the dorsal fins of the parent. The smaller end was embedded in an adhesive mucus-like substance, which was unpigmented or of a whitish colour.

Atherinidae.

Atherina breviceps, C. & V. (Pl. I, fig. 9.)

Several hundreds of these small fish, which are known to Cape fishermen as "Spiering" or "Spierinje," were captured in the month of January at

Kalk Bay. Most of these had the ovaries well developed, and in a few the eggs were fully ripe. As in the case of the European *Atherina* the Cape fish has relatively large eggs—1·48 mm. in diameter. Many oil-globules are present, from ·099 to ·008 mm. in diameter. The yolk is clear and homogeneous. The filaments vary in number and are often very long; one measured was as much as 13 mm. in length. They are much coiled on themselves, and it was difficult to see their distal ends, which in some cases were closely adherent to the surface of the yolk itself.

GADIDAE.

Merluccius capensis, Pappe. (Pl. I, figs. 10, 11; Pl. I, figs. 12, 13.)

The eggs of this fish have been recorded from a mature female, and measured ·97 to ·93 mm., with an oil-globule of ·25 mm. ('Mar. Biol. Rep.,' no. iii, p. 14). Somewhat similar eggs, but of a decidedly larger size, have been procured in tow-nettings in Table Bay. They were 1·35 to 1·26 mm. in diameter, and had an oil-globule of ·28 to ·24 mm. in diameter. In view of the approximate similarity and the characteristics of the larva hatched from the eggs, they are provisionally regarded as those of the stockfish (*M. capensis*).

In the early stages of development the embryo and oil-globule are very clear, in contrast to later stages, in which a dense network of black pigment spreads over these parts, and also, but to a less extent, the yolk. The yolk appears to be slightly vesiculated near the margin, more especially towards the head. The density of the pigment, however, varies much with the light, as shown in fig. 10 and fig. 11. The first shows the appearance under the microscope when first seen, but when the transmitted light has acted on it for a time the chromatophores contract, and the whole assumes a much more transparent aspect.

In the larva the whole body is covered with a dense network of black, branching pigment-cells, with the exception of a spot between the otocyst and eye, which is free of pigment, and the extreme end of the tail, where also pigment is absent. On the yolk near the body and at other isolated places on the yolk are pigment-cells, and the oil-globule is densely covered with such cells. The branchings of the pigment-cells encroach on the fins, and at the rectum there is a dense mass of pigment. The rectum is median in position, and in the early stages the large yolk projects in front of the snout. The oil-globule is postero-ventral in position. Dorsal and ventral fins are fairly deep, and the former commences in the early stages over the head.

On the second day the dorsal and anal fins have narrowed considerably, the broadest part being somewhat posterior to the anus. The yolk has diminished in size, and there is more pigment on it. The length of the larva has increased from 3·3 mm. to 3·36 mm.

Onos capensis, Kaup. (Pl. I, figs. 14, 15 and 16; Pl. II, fig. 17.)

The eggs of this fish were procured in the tow-nets during every month of the year, but were most plentiful during August and September; in these months also the advanced larval stages were procured and an adult form.

The egg is small, its diameter varying from .78 to .72 mm., and is distinguishable by its greenish-yellow oil-globule, which varies from .14 to .16 mm. and has black stellate pigment-spots. A small percentage of these eggs have, in the early stages, two or three oil-globules, which, however, usually fuse into one before hatching takes place. Over the embryo are numerous black pigment-cells.

The larva is about 1.75 mm. in length, and over the head and body to within .48 mm. of the extremity of the tail are many black pigment-spots, a particularly dense mass of these in a branching condition occurring about midway between anus and tail. On the oil-globule, which is situated in a posterior position, are several black stellate spots. The rectum is situated anteriorly and the notochord is multicolumnar. The pectoral fins are fairly well developed, and the dorsal and anal fins, which are not very deep, are devoid of pigment. The yolk is homogeneous.

The larvae were reared to the seventh day, but no marked change occurred after the second day, when the chromatophores opened and spread over the greater portion of the body.

Of the larval forms, procured in the tow-nets the smallest was 2.9 mm. in length and the largest 15.8 mm. The most characteristic feature in all these stages is the development of the ventral fins. In the smaller forms they are elongated and fan-shaped, with four projecting rays, and are deeply pigmented with red and black. In the larger forms they become more elongate, and are pigmented only in their posterior half. In all, except the smallest forms, they were about one-third of the body in length.

In the larger forms a green margin traverses the animal from head to tail on each side of the dorsal fin, the rest of the animal being black, with the exception of a few yellow stellate spots on the head.

This is one of the few cases in which it has been possible to identify the egg by finding all stages in the tow-nettings up to the adult form.

PLEURONECTIDAE.

Synaptura microlepis, Blkr. (Pl. II, figs. 18, 19.)

Certain eggs believed to be those of *Synaptura microlepis* were found near St. Helena Bay ('Mar. Biol. Rep.' no. i, p. 82). They closely resemble the known eggs of *S. pectoralis*, but as this species does not occur on the West Coast it was presumed that they were the eggs of *S. microlepis*.

Similar eggs have been found in the nettings in Table Bay. They were

got in fair numbers during August and the first half of September. They vary in diameter from .85 to .79 mm., and contain from seven to nineteen oil-globules, with diameters ranging from .09 to .016 mm., and these, though scattered about the yolk before the gastrula stage is completed, seem constantly to collect in a group about the time the blastopore closes, after which several become fused so that the largest frequently attains to .13 mm. in diameter. They are yellow in colour with dark margins. Numerous reddish-brown pigment-spots appear on the yolk and on the embryo as it develops, and faint black, branching spots also appear on the yolk, the surface of which is covered with polygonal markings.

The newly-hatched larvae measure from 1.98 to 1.65 mm. in length, and a distinctive feature is the grouping together of the oil-globules in the posterior angle of the yolk-sac. The colouring matter, which is reddish and black by reflected light, is disposed abundantly over the body, fins and yolk. Clear, polygonal markings cover the whole of the surface of embryo and yolk. The position of the rectum is anterior, and the greater portion of the notochord is multicolumnar.

Specimens were kept alive for four days. On the second day the pectoral fins were apparent, and on the third, black, branching pigment had spread on to the caudal region. On the fourth day the development of the mouth was noticeable and the length had increased to 2.7 mm.

These eggs and larvae may be compared with those of *S. pectoralis*, the eggs of which were frequently procured and artificially fertilised during the course of the work of the "Pieter Faure." The eggs of *S. pectoralis* were recorded as varying from .83 to .72 mm. as contrasted with .85 to .79 mm. of this sole. In the former the oil-globules were from one to twelve in number, whereas here they were from seven to nineteen. The greater number of oil-globules is the only distinguishing feature. In the account of the egg and larva of *S. pectoralis* the description of the larva was deferred and is now here noted. The head, body and yolk are covered with branching greenish-yellow pigment-cells, and on the margins of the dorsal and anal fins there is a continuous band of such cells. There is also a band of such pigment across the fins and body midway between the rectum and the extremity of the caudal fin. The region behind this vertical band is entirely destitute of pigment. In contrast to this colouring of the larva of *S. pectoralis* that of *S. microlepis* is reddish.

Arnoglossus capensis, Blgr.

Ten of the eggs of this fish were procured in Table Bay in October and one in March. They measured .72 mm. in diameter, and contained one oil-globule from .13 to .11 mm. in diameter. The yolk was covered with small, clear round spots, and a pinkish tinge appeared on the embryo.

The larvae were in all respects similar to those described in 'Marine Investigations in S. Africa,' vol. iii, p. 133. (Compare Species XXIV, noted further on.)

SCOMBRESOCIDAE.

Hemirhamphus calabaricus, Gthr. (Pl. I, fig. 20.)

Mature eggs of the Needle Fish were procured at Knysna lagoon in December. They were large, being 4 mm. in diameter, and were provided with long filaments. They are not floating eggs, and when placed in water slowly sank to the bottom. The yolk was clear and homogeneous.

The post-larval stages are found in fair abundance in the lagoon in the summer months, and the fish is apparently one of the few sea-fish which comes into the estuarine rivers of S. Africa for the purpose of spawning. I have described elsewhere ('Tr. Roy. Soc. S. Africa,' vol. vi, p. 205) the manner in which this stage is protected from its enemies.

CLUPEIDAE.

Sardina sagax, Jenyns.

The eggs and larvae of this fish have already been described ('Mar. Inv.,' vol. ii, p. 196; and 'Mar. Biol. Rep.,' no. iii, p. 20). Similar eggs and larvae were found in Table Bay in great abundance on September 26, 1916, and three days later in the same locality. They were also found in tow-nettings in the Knysna lagoon in December, 1916.

Engraulis capensis, Gilchr. (Pl. I, figs. 21, 22.)

The occurrence of the eggs of this fish in quantity and the fact that it is frequently found in the stomachs of such fish as the Kabeljaauw, Silver-Fish, etc., seem to indicate that it is in fair abundance in the Cape seas. The fish differs little, as I have pointed out ('Mar. Biol. Rep.,' no. i), from the European Anchovy, but is not made use of in any way in South Africa.

The eggs of this Anchovy were found in abundance during the latter half of January in Table Bay. They were also found in the Knysna lagoon in December, 1916.

They were first found in the course of the work of the "Pieter Faure" off Mossel Bay in the month of January.

The egg and larva closely resemble those of the European Anchovy and are readily recognised, the egg being oval in outline, three Table Bay specimens measuring 1.55 to 1.62 mm. in length and .64 to .59 mm. in breadth. The larva is short, measuring 1.88 mm. in length, and has a characteristic elongate vesiculate yolk (fig. 22).

SPECIES VIII (*Clupea* sp.?).

From the end of September to the beginning of November appears to be the period during which these fish spawn in Table Bay, but their eggs were taken in no great number, the largest single haul being twelve. The diameters of the eggs vary from 1.45 to 1.35 mm., the mean being 1.39 mm. The yolk is vesiculated and they contain no oil-globule. A few faint branching spots about the head and body are the only signs of pigmentation.

The larva is in length about 5.1 mm. and has a hyaline appearance, the yolk is faintly vesiculated and the notochord is unicolumnar. A few faint branching pigment-spots are scattered about the head and body and the rectum is situated a little in advance of the posterior fifth of the animal.

This egg and larva are apparently identical with those described as Species VIII ('Mar. Inv.' vol. ii, p. 199), though both are decidedly larger. They bear a remarkable resemblance to those of the European Sprat (*Clupea sprattus*), though no such fish is known to occur in South African waters.

SPECIES XVIII. (Pl. I, figs. 23, 24.)

The spawning period of these fish is from September to January, but the eggs are most abundant during October. The diameters of the eggs vary very slightly, the maximum being .79 and the minimum .72 mm. They are without oil-globules; a faint yellow tinge suffuses the embryo and the yolk appears as faintly vesiculated near its margin.

On hatching the larva is readily distinguishable on account of the comparatively large size of the yolk-sac, which extends from a little in front of the snout (about .066 mm.) to four-fifths the length of the body.

On the yolk are some clear round markings and lines and a few pale yellow spots. Over the body, chiefly in the dorsal region, are many black dots, and over head, body and fins numerous yellow spots. The notochord is unicolumnar and the rectum at first posterior, but the animal rapidly changes in form, the posterior portion seeming to grow the most rapidly, with the result that in twenty-four hours the rectum is almost in a median position. The chromatophores, which are at first closed, commence to open before the end of the first day, and have covered a great portion of the body, fins and yolk with a network of yellow and black branchings before the end of the second day; on the second day also the pectoral fins show signs of development. On the fourth day the formation of the mouth commences, and it is quite open on the seventh, when the yolk is absorbed and most of the pigment has disappeared from the fins. It was noticed that the larvae on the last day appeared to be endeavouring to obtain food at the bottom of the jar, their jaws moving actively, while they assumed a vertical position head downwards. This seems to be the same egg and larva described as Species XVIII in 'Mar. Inv.' vol. iii, p. 143, though the peculiar early stage with its large yolk was not noted.

SPECIES XXIII. (Pl. I, figs. 25, 26; Pl. II, fig. 27.)

These fish eggs were procured in Table Bay in large numbers during the months of August, September, January and March. They varied in diameter from 1.1 to .99 mm., and contained a single oil-globule, which ranged from .23 to .2 mm. in diameter.

During the development of the embryo the arrangement of the pigment undergoes a marked change. In the early stages, when the embryo has grown to about half the circumference of the egg, large spots of a greyish colour are dotted about irregularly over the yolk on each side of the embryo and about the oil-globule; when, however, the embryo is fully developed these spots disappear, and over it are many similar spots, but of a darker colour, while on the oil-globule there are numerous black, stellate spots.

On emerging from the shell the larva presents the following characteristics: The yolk-sac, in many cases, projects beyond the snout by about .08 mm. Scattered over the head and body, for about three-quarters of its length, are numerous black, stellate and irregular spots and a few minute yellow dots. There is a mass of fine black branching cells over the rectum, which is situated in a posterior position. On the oil-globule, which is situated *anteriorly*, are numerous black stellate spots. There is no sign of pigment on the fins and very little on the yolk. The notochord is multicolumnar and the length about 2.9 mm.

The second day's growth shows that the yellow pigment-cells have increased and are apparently of a deeper tint; they then spread rapidly, large masses being situated between otocyst and eye, at the posterior end of yolk, over the rectum and midway between anus and tail. Soon after the third day's growth a striking peculiarity manifests itself in the development of an upward bend of the anterior portion of the body from about the middle of the yolk, this, in some cases, making an angle with the posterior portion of the body of some 30 or 40 degrees.

Both the eggs and the larva of this fish resemble somewhat those of the Maasbanker, but there is never the extension of the yellow pigment on to the dorsal and anal fins so characteristic of the latter. The eggs of several other species bear a resemblance to these in so far as their diameters and the diameters of their oil-globules are concerned, but the larvae in all these cases differ with regard to the position of their oil-globules. The species is designated XXIII in continuation of the series of eggs and larvae, the parentage of which is, or was when first found, unknown.

The larvae were reared to the sixth day, when they reached a length of 4.26 mm.; the yolk was nearly absorbed and the mouth developing.

SPECIES XXIV (*Arnoglossus*?). (Pl. I, fig. 28; Pl. II, figs. 29, 30.)

The eggs of this fish are plentiful in the Bay during September and December. They vary only slightly in size, their diameters ranging from

·72 to ·69 mm., and they contain from two to seven oil-globules, which are of a yellowish colour, are scattered irregularly about the yolk, and vary from ·08 to ·04 mm. in diameter. A pinkish tinge pervades the embryo from the early stages of development, and the yolk is homogeneous.

In the larva there is a marked regularity in the arrangement of the large pigment-cells. These are of a pink colour suffusing the head region, and about midway between the eye and anus is a large mass on the dorsal side of the body; posterior to this, and about equidistant from each other, are three masses in pairs on the dorsal and ventral sides of the body, branching on to the fins, the first pair being situated over the rectum. Small black stellate spots and dots are scattered over the head and body to within a short distance of the extremity of the tail. The oil-globules are arranged irregularly in the ventral portion of the yolk and are yellow in colour. The notochord is multicolumnar, and the rectum anterior.

The larvae were reared to the ninth day, during which time the following changes were noted: On the second day the pink-coloured cells had spread well on to the fins, where also black branching cells appeared, and the pectoral fins had commenced to develop. On the fourth day the yolk was nearly consumed, the pectoral fins had increased in size and the development of the mouth begun. After this, and up to the ninth day, a gradual change in the coloration of the pigment was observed, the pink changing to a brown, except in the case of the cells over the rectum, which deepened to a red.

These eggs most nearly resemble those of *Arnoglossus capensis* ('Mar. Inv.', vol. iii, p. 133), but the latter have only one oil-globule, and the tuberculate appearance of the fins of the larva was not observed in this case. It may prove that these differences are not essential, but meanwhile it may be well to keep the two kinds separate.

SPECIES XXV.

These minute eggs were obtained in January, and were not observed in the jar containing the tow-netting until after formalin had been added to the water. Their diameters vary between ·56 and ·49 mm., and there is a large perivitelline space. In the preservative the yolk is dark, black with a green margin.

SPECIES XXVI (*Trigla* sp.?). (Pl. I, figs. 31, 32; Pl. II, figs. 33, 34.)

On July 6, 1917, many hundreds of eggs were procured in the tow-nets, about 90 per cent. of which belonged to this species. A few were again got on August 1.

The egg varies in diameter from 1·2 to 1·17 mm., and contains a single oil-globule, which, on account of its comparative smallness (·12 to ·07 mm.) and its salmon-pink colour, in the early stages, gives to the egg a dis-

tinguishing feature. As the embryo progresses, however, the oil-globule becomes darker and eventually assumes a brick-red colour, while on the embryo itself the yellow and black pigment-cells become more clearly marked. Over the superior region of the yolk a few black branching spots are scattered, and there is a network of clear round markings connected by lines over the surface of the yolk.

On the 8th all the eggs had hatched out and showed the following characteristics: Length about 4.16 mm. and greatest breadth 1.04 mm. The position of the rectum is anterior, the notochord is multicolumnar, and the oil-globule is situated ventrally, sometimes being anterior and at others posterior to the vertical axis of the yolk. Over the whole body and yolk are black stellate and yellow branching pigment-cells, and on each of the median fins are black branching spots. There are signs of the development of the pectoral fins, and the whole of the surface of the yolk and dorsal and ventral fins is covered with a network of clear round markings and lines.

On the second day after hatching the most noticeable change was that many fine branching black cells and a few yellow had spread on to the fins, and that the length had increased to 5.05 mm. while the oil-globule had apparently decreased in size, being on the third day only about .048 mm. in diameter.

The size of the egg and the colouring of the larva resemble those of *Trigla kumu*. The oil-globule, though coloured, is, however, much smaller and the newly-hatched larva larger. Besides *Trigla kumu* two other species occur in Cape waters, and the eggs and larvae may belong to one of these.

SPECIES ?

These eggs were procured during the month of December only, and then in no great numbers. They measure in diameter between .89 and .82 mm., and contain a single oil-globule which varies from .18 to .16 mm. in diameter. A brownish tinge suffuses the embryo.

The larva is about 2.1 mm. long, and scattered irregularly over it are numerous spots of brown-coloured pigment, the largest of which are situated before and behind the eyes, near the otocyst, and over the rectum, while the spots on the body branch slightly on to the fins. On the oil-globule, which is in a postero-ventral position, are one or two brown spots. The rectum is close up to the posterior end of the yolk-sac and the notochord multicolumnar. The larvae of this species only lived a few hours. No number is attached to this unknown species as distinctive characters are so few.

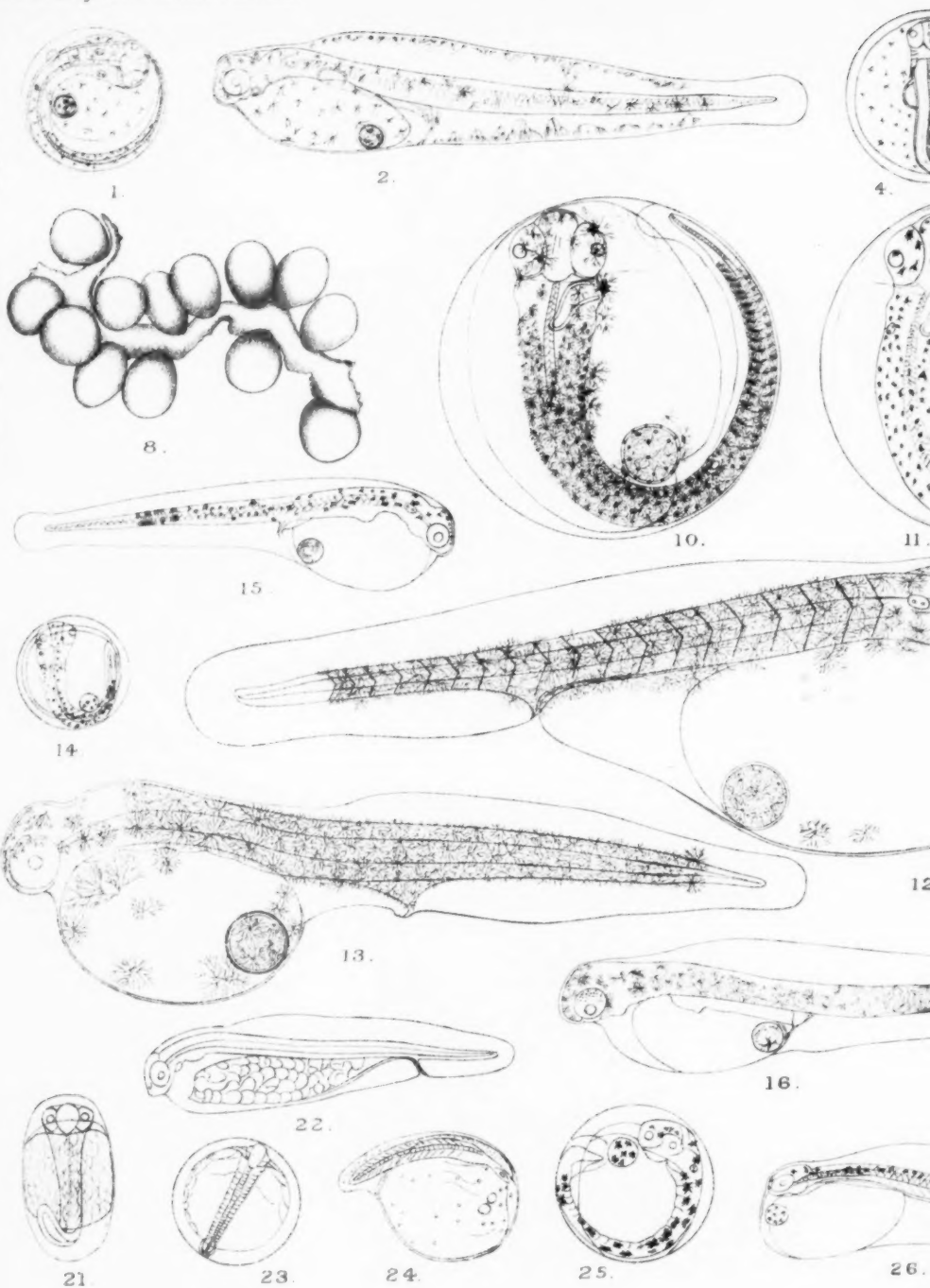
No. of eggs of each species.

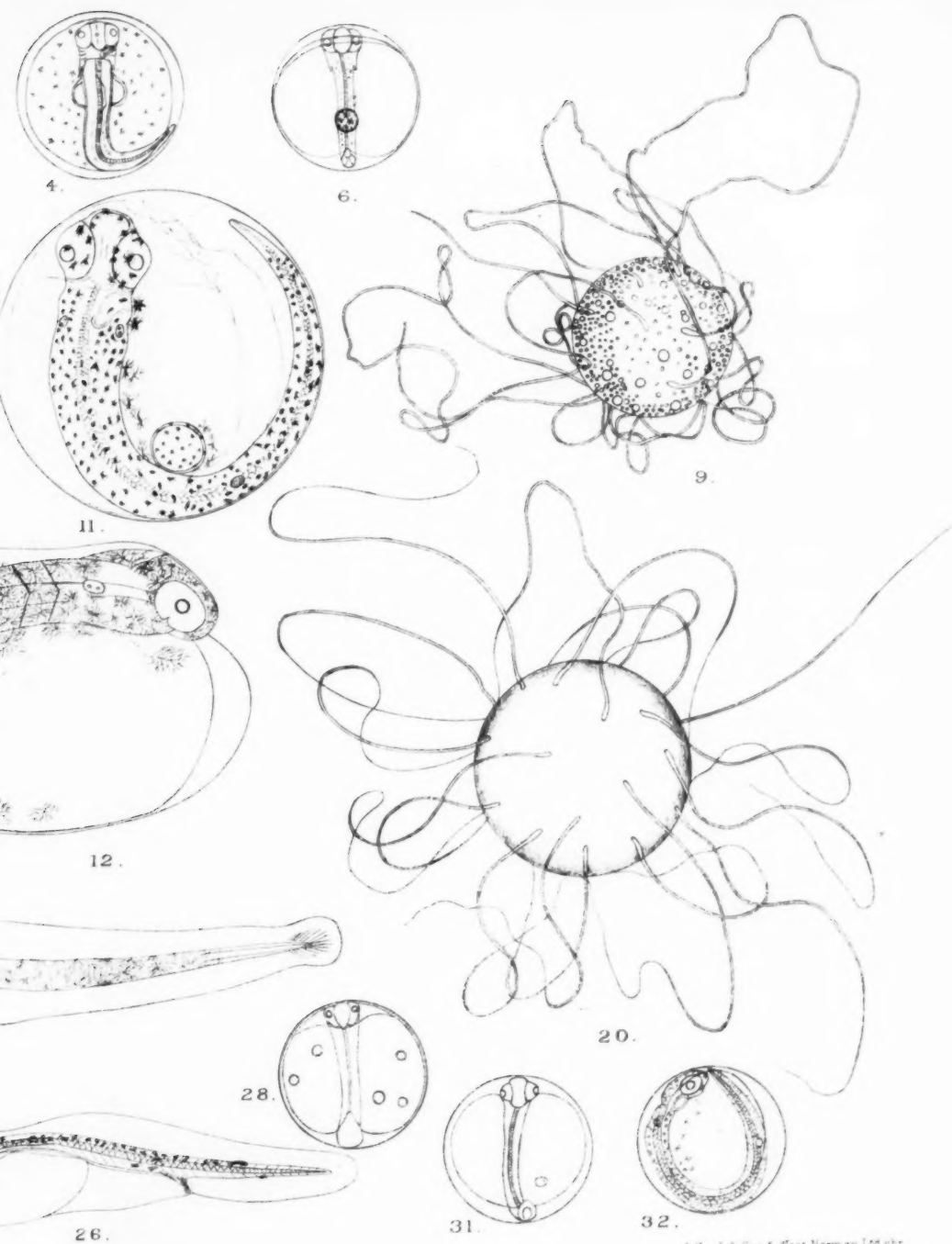
| Date. | Tow-net, Surface or Submerged. | No. of eggs of each species. |
|----------------|---|----------------------------------|
| July 12, 1916 | Surface | <i>Chrysobryx globiceps</i> , 19 |
| " 14, " | " | <i>Agraptus spinifer</i> , 21 |
| " 28, " | " | <i>Trypa kumui</i> , 10 |
| August 3, " | Submerged Surface | <i>Ceram. trachurus</i> , 6 |
| " 4, " | " | <i>Scomber colias</i> , 3 |
| " 10, " | " | <i>Mertensia capensis</i> , 5 |
| " 16, " | " | <i>Oma capensis</i> , 21 |
| " 17, " | " | <i>Gynapturna microlepis</i> , 5 |
| " 22, " | " | <i>Aruglossus capensis</i> , 27 |
| " 29, " | " | <i>Gardina sagax</i> , 12 |
| " 31, " | " | <i>Karyaulis capensis</i> , 6 |
| September 7, " | " | Species VIII., 12 |
| " 8, " | " | Species XVIII., 100* |
| " 12, " | " | Species XXIII., 50* |
| " 15, " | " | Species XIV., 1 |
| " 21, " | " | Species XV., 1 |
| " 26, " | " | Species XXV., 1 |
| " 29, " | " | Species XXVI., 1 |
| October 6, " | " | |
| " 9, " | " | |
| " 12, " | " | |
| " 17, " | " | |
| " 17, " | " | |
| " 20, " | " | |
| " 23, " | " | |

EXPLANATION OF PLATES I AND II.

FIG.

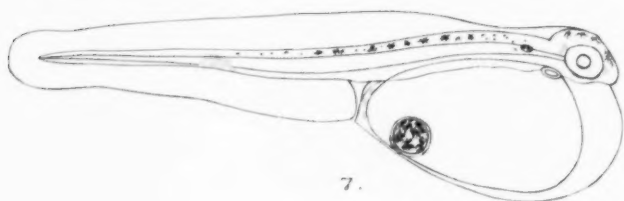
1. Egg of *Trigla kumu*.
2. Larva of *Trigla kumu*.
3. Larva of *Trigla kumu* at a later stage.
4. Egg of *Agriopus spinifer*.
5. Larva of *Agriopus spinifer*.
6. Egg of *Scomber colias*.
7. Larva of *Scomber colias*.
8. Eggs of *Gobius*, sp.
9. Egg of *Atherina breviceps*.
10. Egg of *Merluccius capensis*.
11. Egg of *Merluccius capensis*.
12. Larva of *Merluccius capensis*.
13. Larva of *Merluccius capensis* at a later stage.
14. Egg of *Onos capensis*.
15. Larva of *Onos capensis*.
16. Larva of *Onos capensis* at a later stage.
17. Larva of *Onos capensis*.
18. Egg of *Synaptura microlepis*.
19. Larva of *Synaptura microlepis* (coloured).
20. Egg of *Hemirhamphus calabaricus*.
21. Egg of *Engraulis capensis*.
22. Larva of *Engraulis capensis*.
23. Egg of Species XVIII.
24. Larva of Species XVIII.
25. Egg of Species XXIII.
26. Larva of Species XXIII.
27. Larva of Species XXIII at a later stage.
28. Egg of Species XXIV.
29. Larva of Species XXIV.
30. Larva of Species XXIV at a later stage.
31. Egg of Species XXVI.
32. Egg of Species XXVI at a later stage.
33. Larva of Species XXVI.
34. Larva of Species XXVI at a later stage.



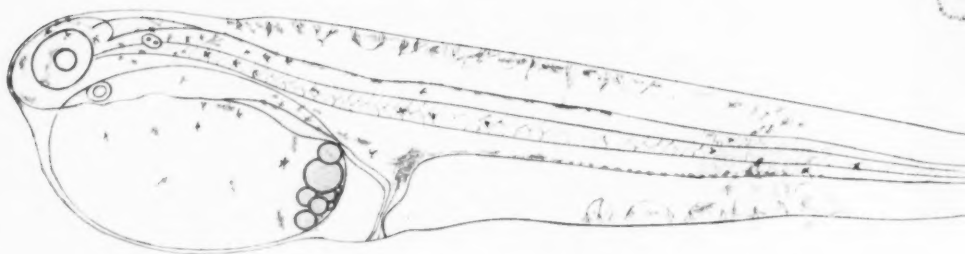




3.



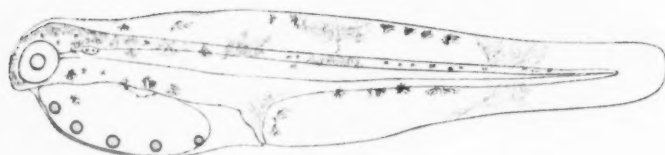
7.



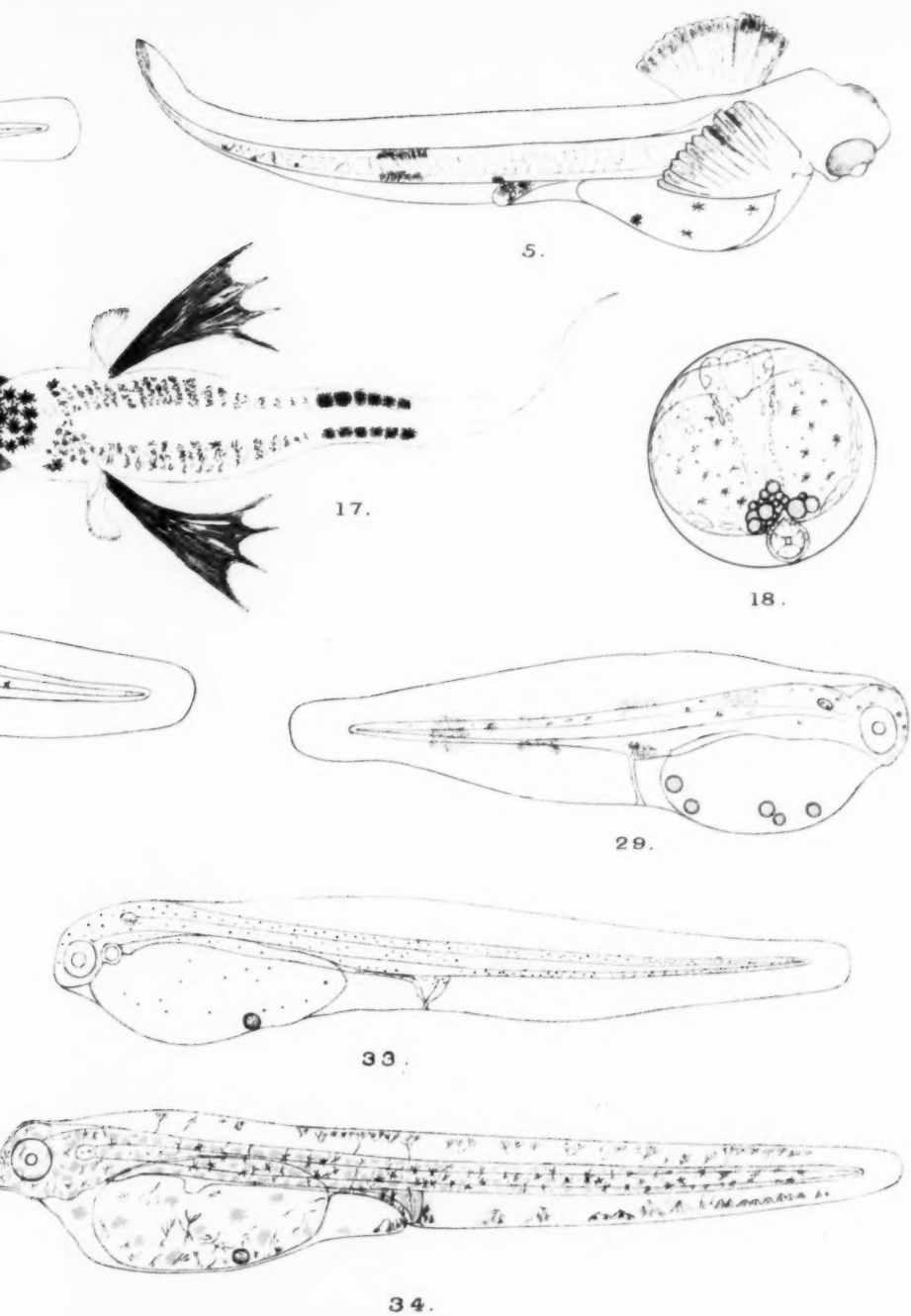
19.



27.



30.



A NOTE ON THE POSSIBILITY OF LONG-RANGE WEATHER FORECASTS.

By J. R. SUTTON, F.R.S.S.A.

Long-range weather forecasts—that is to say, forecasts which profess to foretell the character of coming seasons or periods—may be grouped into three main classes :

(1) The random guesses of the weather prophets, mostly published in cheap almanacs and newspapers. With a little ingenuity these may be made to show a specious accuracy. For instance: suppose it to be known beforehand that, on an average, there have been ten wet days in January: then all that is necessary is to predict ten wet and twenty-one dry days in coming Januarys. The wet and dry days may be assigned to any dates at random, and of these, in the long run, four hits will be scored to three misses. Again, if it be known that there have been, on an average, two wet days in June, the same sort of random guessing will give us, in the long run, thirteen hits to two misses—all of which will look very clever to the uninitiated, especially when an occasional lucky hit with a very heavy rainfall happens to be made.

(2) Forecasts based on cycles—which always break down sooner or later when put to the test of prediction.

(3) Forecasts based on recognised physical or statistical principles. These are much less ambitious than the other two, and, generally speaking, are limited in scope. Two of these, of South African interest, may be mentioned: One, by Claxton, showing that "winter droughts at Durban have invariably been followed by summer droughts in Mauritius";* the other, by Mossman, suggesting a relationship between the temperatures of the Antarctic during August and September and those of Kimberley during the following October to December.† Each of these depends on sound physical principles. The first is based on the easterly drift of barometric depressions

* T. F. Claxton, "Note on the Connection between the Rainfall at Durban and Mauritius," *Trans. S.A. Phil. Soc.*, 1907. A similar sort of correlation probably exists between the rainfall of the River Plate delta and that of south-west Cape Colony.

† R. C. Mossman, "Southern Hemisphere Seasonal Correlations," *Symons's Met. Mag.*, 1913.

across the Indian Ocean; the second depends upon the fact that Antarctic ice moves east-north-east in the current that laves the west coast of South Africa. Thus a knowledge of the conditions at Durban, or in the South Orkneys, will enable us to give a pretty fair forecast of what is to come in Mauritius or in Kimberley respectively.

The object of this slender communication is to show how, in such a climate as ours, the meteorological elements of one month may be modified by those of the month before, and hence that it may become possible to predict in general terms the character of a coming season or period. The elements selected for this purpose are the rainfall of the second half of May and the temperatures of June.

In Table I, col. 1 gives the year:

Col. 2, the rainfalls of May 16-31;

Col. 3, the deviation signs, plus or minus, from the average of the fourteen years 1904-1917;

Cols. 4 and 5, the mean minimum temperatures of the air and the lowest temperatures observed;

Cols. 6 and 7, the mean minimum temperatures on grass and the lowest temperatures observed;

Col. 8, the mean maximum temperatures of the air;

Cols. 9 and 10, the rainfalls of June and the number of rain days in June, for comparison.

TABLE I.—*May Rainfall and June Temperatures.*

| Year. | Rainfall, May 16-31. | Rainfall devia- tion. | Mean minimum tempera- ture of the air | Lowest tempera- ture of the air. | Mean minimum tempera- ture on grass. | Lowest tempera- ture on grass. | Mean maximum tempera- ture of the air. | Rainfall, June. | Rain days, June. |
|---------------|----------------------------|-----------------------------|---|---|--|---|--|--------------------|------------------------|
| | In. | | Degrees Fahr. | Degrees Fahr. | Degrees Fahr. | Degrees Fahr. | Degrees Fahr. | In. | |
| 1904 | ·005 | — | 30·2 | 24·6 | 25·2 | 12·4 | 65·6 | ·427 | 6 |
| 1905 | ·605 | — | 34·4 | 26·3 | 24·2 | 15·4 | 63·2 | ·005 | 1 |
| 1906 | ·620 | — | 37·1 | 28·0 | 26·9 | 17·2 | 65·9 | ·030 | 2 |
| 1907 | ·725 | + | 37·6 | 26·8 | 26·6 | 14·6 | 65·6 | ·060 | 3 |
| 1908 | ·140 | — | 35·1 | 26·1 | 24·0 | 13·2 | 65·3 | ·430 | 1 |
| 1909 | 1·210 | + | 39·8 | 31·8 | 28·8 | 20·6 | 66·7 | ... | ... |
| 1910 | ·060 | — | 34·7 | 26·0 | 22·5 | 13·7 | 63·2 | ·255 | 4 |
| 1911 | 1·510 | + | 36·4 | 26·0 | 25·6 | 14·7 | 61·1 | ·850 | 3 |
| 1912 | 1·950 | + | 36·0 | 30·0 | 26·4 | 19·5 | 62·2 | ·395 | 2 |
| 1913 | ·000 | — | 38·2 | 28·6 | 28·6 | 17·7 | 65·1 | ·355 | 3 |
| 1914 | 1·600 | + | 36·9 | 27·0 | 27·6 | 18·5 | 62·4 | ·565 | 2 |
| 1915 | ·735 | + | 37·6 | 24·0 | 27·4 | 15·7 | 65·2 | ·400 | 4 |
| 1916 | ·000 | — | 34·1 | 27·0 | 20·5 | 13·5 | 66·5 | ... | ... |
| 1917 | ... | — | 35·0 | 24·7 | 22·7 | 10·3 | 63·1 | ·325 | 5 |
| Aver- ages | ·654 | ... | 36·4 | 26·9 | 25·5 | 15·5 | 64·4 | ... | ... |

In six of the given years the rainfall of the second half of May was above the average of the period, and in eight years it was below. Table II epitomises the June temperatures in two groups for these same six and eight years respectively.

TABLE II.—*Showing the Dependence of June Temperatures upon May Rainfall.*

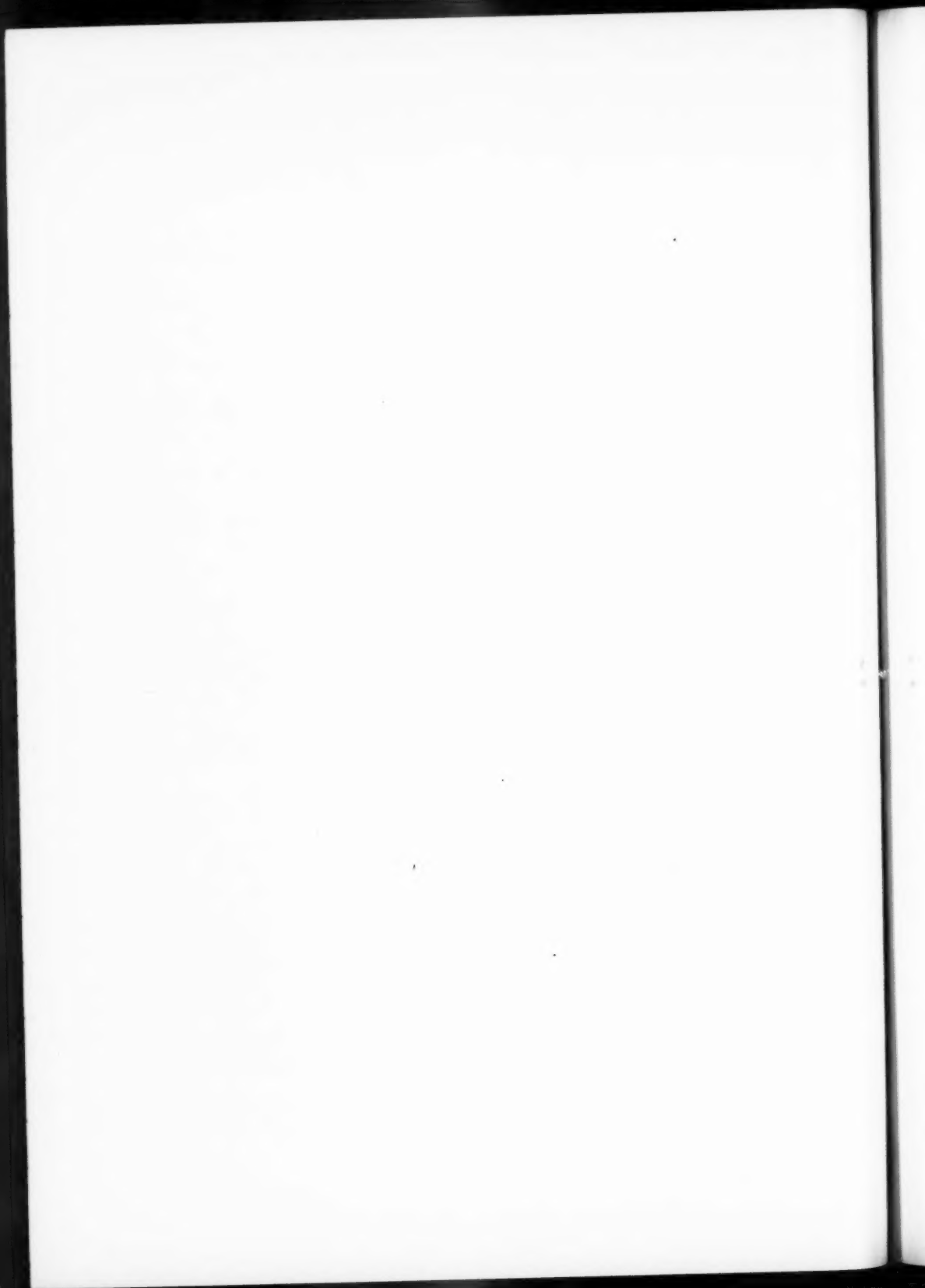
| June averages of— | For rainfall of May 16-31 above the average. | For rainfall of May 16-31 below the average. |
|---|---|---|
| | Degrees Fabr. | Degrees Fabr. |
| Mean minimum temperature | 36.4 | 35.6 |
| Lowest " " " " " | 27.6 | 26.4 |
| Mean temperature on grass | 27.1 | 24.3 |
| Lowest " " " " " | 17.3 | 14.2 |
| Mean maximum temperature | 63.9 | 64.7 |
| Number of times the temperatures fell below 30° F.: | | |
| Air temperatures | 2.50 | 3.75 |
| Grass " " " " " | 21.83 | 25.00 |

The meaning of Table II will be best understood from an example: The average for the whole fourteen years of the lowest June temperatures on grass was 15.5° F.; for the six years in which the May 16-31 rainfall was above the average rainfall the average of the lowest June temperatures on grass was 17.3° F.; for the eight years in which the May 16-31 rainfall was below the average rainfall the average of the lowest June temperatures on grass was 14.2° F.

It follows from Table II that when the second half of May is wet, the following June days tend to be cooler and the nights warmer than when the second half of May is dry. It appears, moreover, that heavier rains towards the end of May determine fewer cold June nights. As it happens, a good many of the cold June nights following a wet May come near the end of the month.

The physical significance of these results is, of course, that dry ground will cool faster by radiation than wet ground will by evaporation and radiation combined. By the same token, because the specific heat of wet ground is greater than that of dry ground, June days following a wet May are cooler than those following a dry May.*

* For information about long-range weather forecasting see W. N. Shaw, 'Forecasting Weather,' 1911, p. 356; also E. B. Garriott, 'Long-Range Weather Forecasts,' 1904. The remarks of R. de C. Ward on changes of climate in 'Climate,' 1908, p. 338 are worth attention.



ON THE ELECTROSTATIC DEFLECTION IN A CATHODE RAY TUBE.

By A. OGG, F.R.S.S.A., Professor of Physics, South African School of Mines and Technology, Johannesburg.

(1) In the ordinary Thomson cathode ray tube for determining the value of e/m for cathode rays we have to allow for the irregularity of the electrostatic field near the edges of the charged plates. Sir T. T. Thomson,* in determining the value of e/m for rays of positive electricity, has given the solution for the case when the rays are parallel to the plates as they enter between them. It is therefore interesting to find the electrostatic deflection given by the complete solution when the rays are projected parallel to the plates but at some distance from them. The following note is written with the object of drawing attention to the method of the calculation, and of comparing the deflection given by the complete solution with that given on the assumption of a uniform field.

Two check calculations are added to test the accuracy of the method of calculation.

The dimensions of the tube given are those of a tube used at Rhodes University College, Grahamstown.

(2) Parallel Plate Condenser.

The complete solution of the semi-infinite parallel plate condenser is given by the Schwarzian transformation—

$$z = C(\beta - \log 1 + \beta + i\pi) \quad (1),$$

where $z = x + iy$. This transforms the infinite plate $y = 0$, and the semi-infinite plate $y = C\pi$ into the real axis of β . The range of β is shown in the following figure:

| | |
|-------------------|------------------|
| $\beta = 0$ | $\beta = \alpha$ |
| $\beta = 0$ | $\beta = -1$ |
| $\beta = -\alpha$ | $\beta = -1$ |
| $\beta = -1.2785$ | |

The further transformation,

$$w = D \log 1 + \beta \quad (2),$$

* 'Phil. Mag.' S. 6, vol. xx, No. 118, Oct., 1910.

where $w = U + iV$, U being the current function, and V , the potential function, gives the solution when the plate $y = C\pi$ is at potential 0, and the plate $y = 0$, is at potential $D\pi$.

The elimination of β between (1) and (2) gives—

$$x = C \left(e^{V/D} \cos^{V/D} - 1 - U/D \right) \quad (3),$$

and

$$y = C \left(e^{V/D} \sin^{V/D} - V/D + \pi \right) \quad (4),$$

when

$$V = 0, y = C\pi,$$

and when

$$V = D\pi, y = 0$$

Now, by the principle of images, the distribution on the upper plate is the same as if the lower plate were a semi-infinite plate, $y = -C\pi$, and the differences of potential between them $2D\pi$.

(3) Electrostatic Deflection of the Cathode Ray.

If a particle of mass on carrying a negative charge is projected from a point on the axis of x with velocity v parallel to x , the equation of motion is—

$$m \frac{d^2 y}{dt^2} = -eY = e \frac{dV}{dy} = e \frac{dU}{dx},$$

or approximately,

$$\frac{mv^2}{e} \frac{d^2 y}{dx^2} = \frac{dU}{dx},$$

$$\frac{mv^2}{e} \frac{dy}{dx} = U - U_0,$$

where U_0 is the value of U , where $\frac{dy}{dx} = 0$.

$$\frac{mv^2}{e} y = \int U dx - U_0 \int dx,$$

but $x = C(\beta - \log 1 + \beta)$, and $U = D \log 1 + \beta$,

therefore—

$$\frac{mv^2}{e} y = CD \int_1^\beta \log 1 + \beta d\beta - U_0 \int dx,$$

$$\frac{mv^2}{e} y = CD \left[1 + \beta \log 1 + \beta - 1 - \beta - \frac{1}{2} \log^2 1 + \beta \right]_{\beta_0}^\beta - U_0 [x]_{l_0}^l.$$

(4) Cathode Ray Tube.

The cathode ray is projected at P parallel to the axis of x , and the electrostatic deflection is produced by the charged plates A and B, which are kept at a constant potential difference. The dimensions of the tube are shown in the figure, the distance between the plates being 0.69 cm.

The stray electrostatic field between P and O_1 deflects the ray before it comes between the plates. A small deflection at O_1 would produce a considerable deflection at the distance Q, even supposing there was no further deflection by the electrostatic field.

Let us first consider the effect of the stray field between P and O_1 .

Take O_1 as origin, and O_1Q as the positive direction of x . The value of β at P is given by—

$$-4.40 = C(\beta - \log - 1 + \beta), \text{ where } 2\pi C = 0.69$$

$$\beta - \log - (1 + \beta) = -4.06,$$

which gives $\beta_P = -36.50$, and $\log - (1 + \beta_P) = 3.57$.

The value of β at the origin is given by—

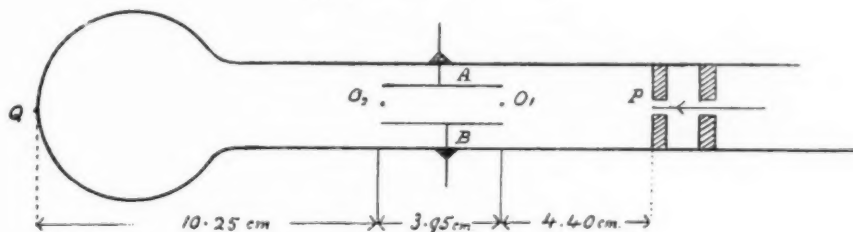
$$\beta_{O_1} = \log - (1 + \beta_{O_1}),$$

$$\beta_{O_1} = -1.2785, \text{ and } \log - (1 + \beta_{O_1}) = -1.2785.$$

The deflection y_1 at O_1 is given by—

$$\frac{mv^2}{e} y_1 = CD \left[1 + \beta \log 1 + \beta - 1 + \beta - \frac{1}{2} \log^2 1 + \beta \right]_P^{O_1} - 4.4 \log 1 + \beta_P$$

$$\frac{mv^2}{e} y_1 = 97.3 CD - 15.9 D.$$



The velocity parallel to y is given by —

$$\begin{aligned} \frac{mv}{e} \frac{dy}{dt} &= U_{O_1} - U_P \\ &= -4.85 D. \end{aligned}$$

To find the deflection due to the field from O_1 to Q we now take O_2 as origin and O_2P as the positive direction of x .

The value of β at Q is given by—

$$C \{ \beta_Q - \log \{ (1 + \beta_Q) \} \} = -10.25,$$

$$\beta_Q - \log - (1 + \beta_Q) = -93.31,$$

which gives $\beta_Q = -88.82$, and $\log 1 + \beta_Q = 4.47$.

An approximate value of β at O_1 is -1 , say $(-1 - \gamma)$,

then $3.95 = C(-1 - \gamma - \log \gamma),$

$$\gamma + \log \gamma = -36.96.$$

An approximate solution is $\gamma = e^{-36.96},$

therefore $U_{O_1} = D \log - (1 + \beta_{O_1}) = -36.96 D.$

We may now regard the ray as projected from O_1 with velocities given by

$$\frac{dx}{dt} = -v,$$

and

$$\frac{mv}{e} \frac{dy}{dt} = -4.85 D.$$

The equation of motion is—

$$\frac{m}{e} \frac{d^2 y}{dt^2} = \frac{dU}{dx},$$

$$-\frac{mv}{e} \frac{dy}{dt} = U + A,$$

but

$$4.85 D = U_{O_1} + A,$$

therefore

$$-\frac{mv}{e} \frac{dy}{dt} = U - U_{O_1} + 4.85 D.$$

$$\frac{mv^2}{e} y_2 = CD \left[1 + \beta \log 1 + \beta - 1 + \beta - \frac{1}{2} \log^2 1 + \beta \right]_{O_1}^{Q_1} - 41.81 \times 14.2 D$$

$$\frac{mv^2}{e} y_2 = 373.3 CD - 593.5 D.$$

The deflection at Q is given by—

$$\frac{mv^2}{e} y = \frac{mv^2}{e} (y_1 + y_2) = 470.6 CD - 609.4 D.$$

If X be the electric intensity between the plates—

$$2\pi D = 0.69 X,$$

and we have seen that

$$2\pi C = 0.69,$$

then

$$\frac{mv^2}{e} y = -61.2 X$$

(5) Check Calculations.

(a) Instead of integrating from P to O_1 in the first instance we might have integrated from P to O_2 . In this case—

$$1 + \beta_P = -35.50, \quad 1 + \beta_{O_2} = 0, \quad 1 + \beta_Q = -87.82,$$

$$\log 1 + \beta_P = 3.57, \quad \log (1 + \beta_{O_2}) = -36.96, \quad \log 1 + \beta_Q = 4.47.$$

Then—

$$\frac{mv^2}{e} y_1 = CD \left[1 + \beta \log 1 + \beta - 1 + \beta - \frac{1}{2} \log^2 1 + \beta \right]_P^{O_2} - 3.57 \times 8.35 D.$$

and—

$$\frac{mv^2}{e} y_2 = CD \left[1 + \beta \log 1 + \beta - 1 + \beta - \frac{1}{2} \log^2 1 + \beta \right]_{O_2}^Q - 41.81 \times 10.25 D.$$

The total deflection is given by—

$$\frac{mv^2}{e} y = \frac{mv^2}{e} (y_1 + y_2) = -905 CD - 457.1 D,$$

$$\frac{mv^2}{e} y = -61.1 X.$$

(b) Let us integrate from P to a point M midway between O_1 and O_2 .

The value of $\log (1 + \beta_M)$ is approximately $-\left(\frac{3.95}{2C} - 1\right)$,

therefore—

$$\log (1 + \beta_M) = -18.98.$$

$$(1 + \beta_P) = -35.50, \quad (1 + \beta_M) = 0, \quad 1 + \beta_Q = -87.82,$$

$$\log 1 + \beta_P = 3.57, \quad \log (1 + \beta_M) = -18.98, \quad \log (1 + \beta_Q) = 4.47.$$

Then—

$$\frac{mv^2}{e} y_1 = CD \left[\overline{1 + \beta} \log \overline{1 + \beta} - \overline{1 + \beta} - \frac{1}{2} \log^2 \overline{1 + \beta} \right]_P^M - 3.57 \times 6.37 D,$$

and—

$$\frac{mv^2}{e} y_2 = CD \left[\overline{1 + \beta} \log \overline{1 + \beta} - \overline{1 + \beta} - \frac{1}{2} \log^2 \overline{1 + \beta} \right]_M^Q - 41.53 \times 12.22 D.$$

The total deflection is given by—

$$\frac{mv^2}{e} y = \frac{mv^2}{e} (y_1 + y_2) = -217.2 CD - 529.8 D,$$

$$\frac{mv^2}{e} y = -60.8 X.$$

The values obtained by the different integrations are in sufficiently good agreement.

(6) Uniform Field.

If we had neglected the irregularities of the field and considered the ray to enter between the plates parallel to x , the deflection would have been given by—

$$\frac{mv^2}{e} y = -3.95(10.25 + 1.97) X,$$

$$= -48.3 X,$$

which differs greatly from that given by the complete solution.

NOTE ON RECURRENTS RESOLVABLE INTO A SEQUENCE OF ODD INTEGERS.

By SIR THOMAS MUIR, LL.D.

(1) In an examination of the properties of the series

$$1, 3, 10, 35, 126, \dots$$

the r^{th} term of which is $C_{2r-1, r-1}$, a determinant made its appearance which for the 4th order is

$$\begin{vmatrix} 1 & 1 & . & . \\ 2 \cdot 3_1 & 1 & 1 & . \\ 4 \cdot 2 \cdot 5_2 & 4 \cdot 3_1 & 1 & 1 \\ 6 \cdot 4 \cdot 2 \cdot 7_3 & 6 \cdot 4 \cdot 5_2 & 6 \cdot 3_1 & 1 \end{vmatrix}$$

and has the value $-9 \cdot 11 \cdot 13$. The fact that the value was the product of a sequence of odd integers led to the discovery that under another form it had in effect been already studied. The alternative form in the case of the 4th order is

$$\begin{vmatrix} 1 & 2 & . & . \\ 3_1 & 1 & 4 & . \\ 5_2 & 3_1 & 1 & 6 \\ 7_3 & 5_2 & 3_1 & 1 \end{vmatrix}$$

and is clearly the more convenient of the two. It was brought forward in 1892 in a paper* connected with the theory of integers, where it had for a companion the determinant

$$\begin{vmatrix} 1 & -2 & . & . \\ 3_1 & 1 & -4 & . \\ 5_2 & 3_1 & 1 & -6 \\ 7_3 & 5_2 & 3_1 & 1 \end{vmatrix}$$

These for the n^{th} order, which we may denote by R_n and R'_n , their discoverer had quite skilfully evaluated, his results being

$$\begin{aligned} R_n &= (-1)^{n-1} (2n+1) (2n+3) \dots (4n-3), \\ R'_n &= (2n+3) (2n+5) \dots (4n-1). \end{aligned}$$

(2) The main object of the present paper is to establish a pair of much more general equalities, and to do so not by a mere extension of Reich's

* Reich, K., "Zur Theorie der quadratischen Reste," *Archiv d. Math. u. Physik.* (2), xi, pp. 176-193.

method, but by a quite different and more rapidly effective procedure. Before entering on this, however, we shall, in introducing four fresh results, establish them by the old method, in order that a knowledge of both may be available.

(3) Increasing the last row of R_n , namely,

$$(2n-1)_{n-1}, (2n-3)_{n-2}, \dots, 5_2, 3_1, 1,$$

by

$$\text{row}_{n-1} \cdot 2 + \text{row}_{n-2} \cdot 2 + \text{row}_{n-3} \cdot 4 + \dots,$$

where the r^{th} of the multipliers

$$2, 2, 4, 10, 28, \dots$$

is $\frac{4}{r} C_{2r-3, r-2}$, we find that the new n^{th} row is divisible by $4n-3$, and that

this factor being removed the row becomes

$$\frac{2}{n}(2n-3)_{n-2}, \frac{2}{n-1}(2n-5)_{n-3}, \dots, \frac{2}{3} \cdot 3_1, \frac{2}{2} \cdot 3_0, 1.$$

It thus follows that, if we denote the resulting determinant by U_n , we have

$$U_n = \frac{R_n}{4n-3} = (-1)^{n-1} (2n+1)(2n+3) \dots (4n-5); \dots \quad (\text{I})$$

for example,

$$U_4 = \begin{vmatrix} 1 & 2 & . & . \\ 3 & 1 & 4 & . \\ 10 & 3 & 1 & 6 \\ 5 & 2 & 1 & 1 \end{vmatrix} = -9 \cdot 11.$$

Note should be taken of the relation between the the series of multipliers and the row which ultimately comes of using them, namely, that *the multipliers when halved give the elements of the said n^{th} row in reverse order.*

(4) Again, by adding to 3 times the n^{th} row of R_n

$$1 \cdot \text{row}_{n-1} + 2 \cdot \text{row}_{n-2} + 5 \cdot \text{row}_{n-3} + \dots$$

we obtain a new n^{th} row which is divisible by $2n+1$ and which on removal of the said factor becomes

$$\frac{2}{n+1}(2n-1)_{n-1}, \frac{2}{n}(2n-3)_{n-2}, \dots, \frac{2}{4} \cdot 5_2, \frac{2}{3} \cdot 3_1, \frac{2}{2} \cdot 1_0;$$

so that, if the resulting determinant be denoted by V_n , we have

$$V_n = (-1)^{n-1} 3(2n+3)(2n+5) \dots (4n-3) \dots \quad (\text{II})$$

Here the multipliers are

$$1, 2, 5, 14, \dots, \frac{2}{n}(2n-3)_{n-2}$$

and the last row of V_n is

$$\frac{2}{n+1}(2n-1)_{n-1}, \dots, 14, 5, 2, 1.$$

(5) Similarly we may treat R'_n as R_n has been treated in § 3, the difference being that the addition of the sum of multiples of rows is made to -3 times the n^{th} row, and that the factor removed is $-(4n-1)$. Calling the new determinant U'_n , which, be it noted, has the same last row as U_n , we have

$$U'_n = 3(2n+3)(2n+5) \dots (4n-3) \quad \text{. . . (III)}$$

(6) Lastly, we may treat R'_n as R_n has been treated in § 4, the difference being that the addition of the sum of multiples of rows is made to -5 times the n^{th} row, and that the factor removed is $-(2n+3)$: so that if the resulting determinant be denoted by V'_n we have

$$V'_n = 5(2n+5)(2n+7) \dots (4n-1); \quad \text{. . . (IV)}$$

for example,

$$V' \equiv \begin{vmatrix} 1 & -2 & . & . & . \\ 3 & 1 & -4 & . & . \\ 10 & 3 & 1 & -6 & . \\ 35 & 10 & 3 & 1 & -8 \\ 42 & 14 & 5 & 2 & 1 \end{vmatrix} = 5 \cdot 15 \cdot 17 \cdot 19.$$

(7) Comparing the equalities obtained in §§ 4, 5, we reach the otherwise curious result

$$U'_n = (-1)^{n-1} V_n; \quad \text{. (V)}$$

for example,

$$U'_3 \equiv \begin{vmatrix} 1 & -2 & . & . & . \\ 3 & 1 & -4 & . & . \\ 10 & 3 & 1 & -6 & . \\ 35 & 10 & 3 & 1 & -8 \\ 14 & 5 & 2 & 1 & 1 \end{vmatrix} = \begin{vmatrix} 1 & 2 & . & . & . \\ 3 & 1 & 4 & . & . \\ 10 & 3 & 1 & 6 & . \\ 35 & 10 & 3 & 1 & 8 \\ 42 & 14 & 5 & 2 & 1 \end{vmatrix}.$$

(8) The four equalities upon which depends the finding of the new n^{th} rows in §§ 3, 4, 5, 6 are properties of the series

$$1, 3, 10, 35, 126, \dots$$

referred to in § 1. They are all, however, reducible to one fundamental equality, namely,

$$(2m+1)_m + \frac{1}{2}(2m-1)_{m-1} \cdot 1_0 + \frac{1}{3}(2m-3)_{m-2} \cdot 3_1 + \dots + \frac{1}{m+2}(2m+1)_m \\ = \frac{3}{2}(2m+1)_m$$

or, if we call the members of the series t_1, t_2, \dots

$$\left(1, \frac{1}{2}, \frac{1}{3}, \dots, \frac{1}{m+2} \right) (t_{m+1}, t_m, \dots, t_1, 1) (1, t_1, \dots, t_{m+1}) = \frac{3}{2} t_{m+1}.$$

It is not essentially different from Reich's principal equality (p. 181) which he proves gradationally, that is to say, by proceeding from one value of m to the next higher.

(9) Let us now consider a determinant differing from R_n in the last row, which instead of being

$$(2n-1)_{n-1}, (2n-3)_{n-2}, \dots, 5_2, 3_1, 1$$

is

$$(2n+m-4)_{n-1}, (2n+m-6)_{n-2}, \dots, (m+2)_2, m_1, 1.$$

This determinant may appropriately be denoted by $R_n(m)$, which implies, of course, that what we have hitherto called R_n would now be denoted by $R_n(3)$.

On account of the equality

$$r_n = (r-1)_n + (r-1)_{n-1}$$

the last row of $R_n(m)$ may be partitioned into two, namely, into

$$\begin{aligned} &+ (2n+m-5)_{n-1}, (2n+m-7)_{n-2}, \dots, (m+1)_2, (m-1)_1, 1, \\ &+ (2n+m-5)_{n-2}, (2n+m-7)_{n-3}, \dots, (m+1)_1, \quad 1, \quad 0; \end{aligned}$$

so that we have at once the recurrent law of formation

$$R_n(m) = R_n(m-1) - 2(n-1) R_{n-1}(m+1) \quad \dots \quad (VI)$$

If now we view $R_n(3)$ as known, namely,

$$R_n(3) = (-1)^{n-1} (2n+1) (2n+3) \dots (4n-3)$$

we can readily evaluate $R_n(m)$. For, when m is 1 the n^{th} row of the determinant is identical with the $(n-1)^{\text{th}}$ row save in the n^{th} place, so that we have

$$R_n(1) = - (2n-3) R_{n-1}(3)$$

whence by substitution

$$R_n(1) = (-1)^{n-1} (2n-3) (2n-1) \dots (4n-7);$$

and, in the next place, putting $m=2$ in (VI) we have

$$R_n(2) = R_n(1) - 2(n-1) R_{n-1}(3)$$

whence by substitution

$$R_n(2) = (-1)^{n-1} (2n-1) (2n+1) \dots (4n-5).$$

We thus have a formula for $R_n(m)$ which holds for three consecutive values of m ; and, this being the case, the recurrence formula (VI) enables us to show that it holds generally, namely,

$$R_n(m) = (-1)^{n-1} (2n+2m-5) (2n+2m-3) \dots (4n+2m-9) \quad \dots \quad (VII)$$

(10) It is of importance, however, not to assume a knowledge of the value of $R_n(3)$, but to establish another recurrence-formula which is effective without it, namely,

$$R_n(m) = - (2n+2m-5) R_{n-1}(m+2) \quad \dots \quad (VIII)$$

This is done by performing on $R_n(m)$ the operation

$$(2n-2) \cdot \text{row}_n - \text{row}_{n-1} \\ - (m-1) \left\{ \text{row}_{n-2} + \frac{1}{2} (m+2)_1 \cdot \text{row}_{n-3} + \frac{1}{3} (m+4)_2 \cdot \text{row}_{n-4} + \dots \right\}$$

which enables us to remove from the last row the factor $2n + 2m - 5$ and leave the row

$$(2n + m - 4)_{n-2}, (2n + m - 6)_{n-3}, \dots, (m + 2)_1, 1, 0$$

thus giving us

$$(2n - 2) R_n(m) = - (2n - 2) \cdot (2n + 2m - 5) R_{n-1}(m + 2)$$

from which we have only to remove the common factor.

By applying (VIII) to itself and repeating the operation we obtain

$$\begin{aligned} R_n(m) &= (-1)^2 (2n + 2m - 5) (2n + 2m - 3) R_{n-2}(m + 4) \\ &= \dots \\ &= (-1)^{n-1} (2n + 2m - 5) \dots (4n + 2m - 9) \cdot R_1(m + 2n - 2) \end{aligned}$$

and R_1 is 1 for all arguments.

(11) The complicated operation which brings about the removal of the factor $2n + 2m - 5$ in the preceding paragraph is based on a property of the numbers 1, 3, 10, 35, . . . $(2n - 1)_{n-1}$, which, on the other hand, is simple and orderly, namely,

$$\begin{aligned} & \frac{(2p + 2 + q)_{p+1} - (2p + 3)_{p+1}}{q - 1} \\ &= (2p + 1)_p \cdot q_0 + \frac{1}{2} (2p - 1)_{p-1} (q + 2)_1 + \frac{1}{3} (2p - 3)_{p-2} (q + 4)_2 + \dots \\ & \quad + \frac{1}{p + 1} (1)_0 (q + 2p)_p \dots \dots \dots \quad \text{(IX)} \end{aligned}$$

where the possibility of division on the left-hand side is attested by the vanishing of the numerator when q is put equal to 1. It may be viewed as a generalisation of the theorem quoted in § 8: for on putting $q = -1$ the left-hand member here becomes

$$\frac{(2p + 3)_{p+1} - (2p + 1)_{p+1}}{2} \quad \text{i. e.} \quad \frac{3p + 4}{2(p + 2)} \cdot (2p + 1)_p$$

after which we have only got to add $\frac{1}{p + 2} \cdot (2p + 1)_p$ in order to complete the transformation.

(12) R' may be generalised in its last row exactly as R_n has been, the resulting determinant being denoted by $R'_n(m)$, and there being a series of companion theorems. For example, as analogues to (VI) and (VII) we have

$$R'_n(m) = R'_n(m - 1) + 2(n - 1) R'_{n-1}(m + 1) \quad \text{(X)}$$

$$R'_n(m) = (2n + 2m - 3) (2n + 2m - 5) \dots (4n + 2m - 7) \dots \quad \text{(XI)}$$

(13) With the closely resembling values of $R_n(m)$ and $R'_n(m)$ before us it is easy to suggest relations the proofs of which would form interesting exercises in the transformation of determinants. Thus, since from § 9 we have

$R_n(m+1) = (-1)^{n-1}(2n+2m-3)(2n+2m-5) \dots (4n+2m-7)$
 it follows with the help of (XI) that

$$R_n(m+1) = (-1)^{n-1}R_n(m)$$

i. e., when n is 5

$$\begin{vmatrix} 1 & 2 & . & . & . \\ 3 & 1 & 4 & . & . \\ 10 & 3 & 1 & 6 & . \\ 35 & 10 & 3 & 1 & 8 \\ (m+7)_4 & (m+5)_3 & (m+3)_2 & (m+1)_1 & 1 \end{vmatrix} = \begin{vmatrix} 1 & -2 & . & . & . \\ 3 & 1 & -4 & . & . \\ 10 & 3 & 1 & -6 & . \\ 35 & 10 & 3 & 1 & -8 \\ (m+6)_4 & (m+4)_3 & (m+2)_2 & m_1 & 1 \end{vmatrix}$$

RONDEBOSCH, S.A.;

August 14th, 1918.

ON *RANA ORNATISSIMA*, BOCCAGE, AND *R. RUDDI*, BLGR.

BY G. A. BOULENGER, LL.D., D.Sc., F.R.S.

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Thanks to the kindness of Miss M. Wilman I have been able to examine the frog from Southern Rhodesia, which has recently been referred, with some doubt, to *Rana ruddi* by Hewitt and Power,* and which, from the notes of these authors, I suspected would prove to belong to a different species—a suspicion now confirmed by this examination, the specimen being referable to *R. ornatissima*.

It may be useful to give comparative descriptions of the two frogs in order to avoid future confusion, and also to present, in synoptic form, the distinctive characters of the eight species which make up the very natural subgenus, restricted to Africa, named *Hildebrandtia* by Nieden (type: *R. ornata*, Peters), and which have never been properly contrasted before.

Subgenus *HILDEBRANDTIA*, Nieden.

Vomerine teeth in small groups or short series touching the anterior corners of the choanae. Fingers and toes not dilated at the tips; outer metatarsals bound together. Nasals narrow and widely separated from each other and from the frontoparietals; ethmoid largely exposed above; zygomatic process of squamosal very short. Clavicles very slender, curved, widely separated from each other on the median line; omosternal style not forked at the base. Terminal phalanges obtuse.

Stout burrowing forms with strong, compressed inner metatarsal tubercle. Males with external vocal sacs.

SYNOPSIS OF THE SPECIES.

I. No dorso-lateral fold; head $1\frac{1}{3}$ times as broad as long; snout broadly rounded; tympanum larger than eye; tibio-tarsal articulation reaching tympanum; tibia $2\frac{2}{3}$ times in length of head and body; toes barely $\frac{1}{2}$ webbed *R. macrotympanum*, Blgr., 1912 (Gallaland).

II. A more or less distinct dorso-lateral glandular fold; head not or but little broader than long.

* 'Trans. R. Soc. S. Afr.' iii, 1913, p. 168.

- A. First finger longer than second, as long as third; tibio-tarsal articulation reaching nostril; tibia $2\frac{1}{5}$ times in length of head and body; foot $2\frac{2}{3}$ times in length of head and body; toes $\frac{1}{3}$ webbed; tympanum as large as eye. *R. moeruensis*, Blgr., 1901 (Katanga).
- B. First finger not longer than second, shorter than third; tibio-tarsal articulation reaching eye; tibia $2\frac{1}{4}$ to $2\frac{1}{2}$ times in length of head and body.

Snout obtusely pointed, projecting, little longer than eye; tympanum nearly as large as eye; interorbital space narrower than upper eyelid; foot $2\frac{3}{4}$ times in length of head and body; toes $\frac{1}{2}$ webbed, only one phalanx of third free.

R. ornata, Peters, 1878 (Somaliland to Portuguese E. Africa).

Snout obtusely pointed, projecting, as long as or a little longer than eye; tympanum $\frac{2}{3}$ to $\frac{3}{4}$ diameter of eye; interorbital space narrower than upper eyelid; foot $2\frac{1}{3}$ to $2\frac{2}{3}$ times in length of head and body; toes $\frac{1}{3}$ webbed; two phalanges of third free.

R. ornatissima, Bocage, 1879 (Angola, Rhodesia).

Snout pointed, strongly projecting, much longer than eye; tympanum $\frac{1}{2}$ diameter of eye; interorbital space as broad as upper eyelid; toes $\frac{1}{2}$ webbed. *R. togoensis*, Blgr., n. n.* (Togoland).

Snout vertically truncate in front of nostrils; tympanum about $\frac{1}{2}$ diameter of eye; interorbital space narrower than upper eyelid; toes $\frac{1}{3}$ webbed, two phalanges of third free.

R. miotympanum, Blgr., n. n.† (Angola).

- C. First finger not longer than second, shorter than third; tibio-tarsal articulation reaching tympanum; tibia $2\frac{2}{3}$ to $2\frac{3}{4}$ times in length of head and body.

Snout obtusely pointed, projecting; tympanum at least $\frac{3}{4}$ diameter of eye; foot 3 times in length of head and body; toes nearly $\frac{1}{2}$ webbed. *R. budgetti*, Blgr., 1903 (Gambia).

Snout rounded, not projecting; tympanum $\frac{2}{3}$ diameter of eye; foot $2\frac{1}{3}$ to $2\frac{2}{3}$ times in length of head and body; toes hardly $\frac{1}{3}$ webbed. *R. ruddi*, Blgr., 1907 (Beira).

RANA ORNATISSIMA.

Bocage, Journ. Sc. Lish., vii, 1879, p. 98, and Herp. Ang., p. 157, pl. xvi, fig. 2 (1895); Bouleng., Ann. and Mag. N. H. (7), xvi, 1905, p. 107.

Vomerine teeth in transverse or slightly oblique, straight or feebly curved series close to the anterior corners of the choanae, the series as long as or a little longer than the distance between them.

Habit stout. Head as long as broad or a little broader than long, very

* *Hildebrandtia ornatissima*, Nieden, 1908, nec Bocage.

† *Hildebrandtia angolensis*, Nieden, 1908 (name pre-occupied in genus *Rana*).

convex; snout obtusely pointed, projecting beyond the mouth, as long as or a little longer than the eye; canthus rostralis rounded; loreal region oblique, concave; nostril a little nearer the eye than the end of the snout; distance between the nostrils much greater than the interorbital width, which is much less than that of the upper eyelid; tympanum very distinct, $\frac{3}{4}$ to $\frac{5}{8}$ the diameter of the eye, 2 to 3 times its distance from the latter.

Fingers short, obtusely pointed, third longest, first as long as or slightly shorter than the second, longer than the fourth; subarticular tubercles moderately large, moderately prominent.

Tibio-tarsal articulation reaching the eye; heels meeting or slightly overlapping when the limbs are folded at right angles to the body; tibia 3 to $3\frac{1}{2}$ times as long as broad, $2\frac{1}{2}$ to $2\frac{3}{4}$ times in length from snout to vent, a little shorter than the fore limb, as long as or a little longer than the foot. Toes rather short, obtusely pointed, $\frac{1}{2}$ webbed, 3 or $3\frac{1}{2}$ phalanges of fourth and 2 of third and fifth free; subarticular tubercles small, feebly prominent; inner metatarsal tubercle hard and compressed, as long as or a little shorter than the inner toe; no outer tubercle; no tarsal fold.

Upper parts smooth; a feebly prominent dorso-lateral glandular fold. Lower parts smooth, or belly granulate on the sides and behind.

Olive brown or pale green, with dark olive or blackish, often pink-edged spots which may be insuliform or form two longitudinal series on the head and back, from the upper eyelids, and two on each side of the dorso-lateral fold, which is yellowish or pink; a yellowish or pink streak on the canthus rostralis, on the outer border of the upper eyelid, and above the temple; a dark band on the loreal region and on the temple; a more or less oblique white streak in front of the eye; sometimes a whitish ring round the tympanum; a light streak above the edge of the upper lip, which is dark brown or black. Belly whitish, lower surface of limbs yellow; throat dark brown or marbled with dark brown, with a large angular or Y-shaped light marking on each side.

Male with a very large, bilocular external vocal sac, the anterior part black, the posterior white, protruding through a slit on the side of the throat, terminating close to the middle of the base of the arm, the slit as long as the orbit. Fore limbs not thickened; in the breeding season a brown callous pad is present on the inner side of the forearm, at the base of the second and third fingers, and similar callosities cover the upper surface of the three inner fingers.

The type of this species came from Bihé, east of Benguela, and the British Museum possesses many specimens obtained by Dr. Ansorge in the same district as well as in other localities in Mossamedes. Southern Rhodesia may now be added to the habitat.

Measurements, in Millimetres.

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. |
|---------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| | ♂ | ♀ | ♀ | ♀ | ♀ | ♀ | ♀ | ♀ | ♀ | ♀ |
| From snout to vent . . . | 70 | 75 | 56 | 53 | 50 | 48 | 46 | 46 | 44 | 49 |
| Head | 23 | 27 | 21 | 19 | 18 | 18 | 16 | 16 | 15 | 18 |
| Width of head | 24 | 30 | 21 | 18 | 20 | 18 | 17 | 18 | 16 | 18 |
| Snout | 9 | 11 | 8 | 7 | 7 | 6.5 | 6.5 | 7 | 6 | 7 |
| Eye | 7 | 8 | 7 | 6 | 6 | 6 | 5.5 | 5.5 | 6 | 6 |
| Interorbital width . . | 3.5 | 4 | 3 | 3 | 3 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Tympanum | 5 | 6 | 5.5 | 4.5 | 4.5 | 4 | 4 | 4 | 4 | 4.5 |
| Fore limb | 33 | 36 | 27 | 24 | 24 | 23 | 22 | 23 | 22 | 24 |
| 1st finger | 3.5 | 4 | 3.5 | 3.5 | 3.5 | 3.5 | 3 | 3 | 3 | 4 |
| 2nd finger | 4 | 4 | 4 | 4 | 4 | 4 | 3.5 | 3.5 | 3 | 4 |
| 3rd finger | 5.5 | 6 | 5.5 | 5 | 5 | 5 | 4.5 | 4.5 | 4 | 5.5 |
| 4th finger | 3 | 3.5 | 3 | 2.5 | 3 | 3 | 2.5 | 2.5 | 2 | 3 |
| Hind limb | 90 | 103 | 77 | 70 | 66 | 66 | 62 | 66 | 61 | 71 |
| Tibia | 31 | 34 | 24 | 21 | 21 | 20 | 19 | 21 | 19 | 23 |
| Foot | 26 | 31 | 22 | 20 | 20 | 20 | 18 | 19 | 18 | 21 |
| Inner toe | 3.5 | 4.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3 | 3 | 3 | 3.5 |
| Inner metatarsal tubercle | 4 | 4 | 3 | 3 | 3 | 3.5 | 2.5 | 2.5 | 2.5 | 3 |

1, 2. Bingondo, between Benguela and Bihé. 3. Ponang Kuma, Mossamedes.
 4-8. Cafita swamp, Mossamedes. 9. Konondoto, Mossamedes. 10. Eldorado,
 S. Rhodesia.

RANA RUDDI.

Bouleng., Proc. Zool. Soc., 1907, p. 480, pl. xxii, fig. 1.

Vomerine teeth in small groups or short transverse series close to the anterior corners of the choanae, the series shorter than the distance between them.

Habit very stout. Head a little broader than long, very convex; snout rounded, not projecting beyond the mouth, as long as the eye; canthus rostralis rounded; loreal region oblique, rather strongly concave; nostril equidistant from the eye and from the end of the snout, or a little nearer the former; distance between the nostrils much greater than the interorbital width, which is much less than that of the upper eyelid; tympanum very distinct, $\frac{3}{4}$ the diameter of the eye, 2 to 3 times its distance from the latter.

Fingers very short, obtusely pointed, third longest, first and second equal and longer than the fourth; subarticular tubercles feeble.

Tibio-tarsal articulation barely reaching the tympanum; heels meeting when the limbs are folded at right angles to the body; tibia 3 times as long as broad, $2\frac{3}{8}$ to $2\frac{2}{3}$ times in length from snout to vent, shorter than the fore limb, a little longer than the foot, which is $2\frac{1}{3}$ to $2\frac{2}{3}$ times in length from snout to vent. Toes short, obtusely pointed, hardly $\frac{1}{2}$ webbed, 3 phalanges of fourth and 2 of third and fifth free; subarticular tubercles small, feebly prominent; inner metatarsal tubercle hard and strongly compressed, as long as the inner toe; no outer tubercle; no tarsal fold.

Upper parts with flat smooth warts of unequal size; a very indistinct dorso-lateral fold. Lower parts smooth, sides of belly feebly areolate.

Dark brown above, with yellowish streaks on the head and body, viz. a very narrow one on the vertebral line and a broader one from the end of the snout along the canthus rostralis and the outer border of the upper eyelid to above the tympanum, where it bifurcates, the upper branch extending to above the vent, the lower descending obliquely to the groin; usually a yellowish bar across the occiput; a yellowish streak above the blackish edge of the upper lip, continued to above the shoulder; a white oblique line in front of the eye and a white circle round the tympanum; limbs with dark and pale bars; hinder side of thighs yellowish, marbled with black. Throat and breast dark brown, or marbled with dark brown, with a Y-shaped white marking on each side; belly white.

Male with large, bilocular external vocal sacs, each protruding through a slit on the side of the throat, terminating close to the middle of the base of the arm, the slit as long as the orbit; fore limb not thickened, without nuptial callosities.

Measurements, in Millimetres.

| | ♂ | ♂ | ♀ |
|-------------------------------------|-----|-----|-----|
| From snout to vent | 48 | 46 | 46 |
| Head | 16 | 15 | 15 |
| Width of head | 17 | 17 | 17 |
| Snout | 6 | 6 | 6 |
| Eye | 6 | 6 | 6 |
| Interorbital width | 2.5 | 2.5 | 2.5 |
| Tympanum | 4 | 4 | 4 |
| Fore limb | 21 | 21 | 23 |
| 1st finger | 3 | 3 | 3 |
| 2nd finger | 3 | 3 | 3 |
| 3rd finger | 4 | 4 | 4 |
| 4th finger | 1.5 | 2 | 2 |
| Hind limb | 56 | 57 | 59 |
| Tibia | 18 | 18 | 19 |
| Foot | 17 | 17 | 17 |
| Inner toe | 3 | 3 | 3 |
| Inner metatarsal tubercle | 3 | 3 | 3 |

This description is taken from the three type specimens from Beira, Portuguese East Africa, forming part of a collection made by Mr. Claude Grant, and presented to the British Museum by Mr. C. D. Rudd, after whom the species is named.

ON A NEW LIZARD OF THE GENUS *LATASTIA* FROM
SOUTHERN RHODESIA.

By G. A. BOULENGER, LL.D., D.Sc., F.R.S.

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The occurrence in Southern Rhodesia of *Eremias nitida*, Gthr., a species inhabiting Nigeria and Togoland, has been reported by Hewitt and Power ('Trans. R. Soc. S. Afr.' iii, 1913, p. 156), and seemed so highly improbable to me that I applied to Mr. Power for the loan of the specimen on which the identification was based, and this favour was most obligingly granted by Miss Wilman. The result of my examination is that the lizard is no *Eremias*, but a *Latastia*, a genus established by Bedriaga for species formerly confounded with *Lacerta*, but which differ in having keeled subdigital scales—a character in which they agree with *Eremias*. The only character separating the latter from *Latastia* is the position of the nostril, widely separated from the first upper labial shield, which is not the case in the lizard from Eldorado, here described as a new species, with which the name of its discoverer, Mr. O. A. Kidwell, is associated. The discovery is a very important one, as it extends the range of the genus, previously unknown from South Africa.

LATASTIA KIDWELLI, sp. n.

Body scarcely depressed. Head moderately depressed, $1\frac{1}{2}$ times as long as broad, its depth equal to the distance between the centre of the eye and the tympanum, its length $4\frac{1}{3}$ times in length to vent; snout obtusely pointed, as long as postocular part of head, with sharp canthus and vertical loreal region. Pileus $1\frac{1}{3}$ times as long as broad. Neck as broad as the head. Hind limb reaching the shoulder; foot $1\frac{1}{3}$ times as long as the head; toes slender, compressed.

Nostril pierced between 4 shields; nasals forming a suture behind the rostral, the suture $\frac{2}{3}$ the length of the frontonasal, which is much broader than long and broader than the internarial space; prefrontals forming a median suture; frontal slightly longer than its distance from the end of the snout, $1\frac{1}{3}$ times as long as broad, rounded in front, much narrower behind, grooved along the anterior $\frac{2}{3}$; parietals $1\frac{1}{2}$ times as long as broad, with straight outer border; interparietal $2\frac{1}{2}$ times as long as broad, separated from the small occipital by a very small shield. Four supraoculars, first

and fourth small, the three anterior in contact with the frontal, the second and third equal; 6 superciliaries, separated from the supraoculars by a complete series of granules. Lower eyelid opaque, with vertically enlarged scales in the middle. Rostral not entering the nostril; 2 superposed post-nasals; anterior loreal $\frac{1}{3}$ the length of the second; 5 upper labials anterior to the subocular, which is narrower beneath than above; temporal scales granular; a very narrow tympanic shield.

Four pairs of chin-shields, and a very small fifth, first three in contact in the middle; 25 gular scales between the symphysis of the chin-shields and the median collar-plate, increasing in size and imbricate towards the collar; no gular fold; collar with strongly serrated edge, composed of 10 plates.

Scales strongly keeled, granular on the nape, rhombic and feebly imbricate on the body; the keels distinct on the lateral scales down to the ventrals; 42 scales across the middle of the body, 32 in a transverse series between the hind limbs. Ventral plates in 8 longitudinal series, the outer plate small, and 26 transverse series. Preanal plates small, forming pairs in the middle.

A series of 7 large transverse plates under the forearm. Scales on upper surface of tibia keeled, much smaller than dorsals. 13-14 femoral pores. Subdigital lamellæ bicarinate, 23 under the fourth toe.

Caudal scales strongly keeled, upper oblique, 26 in the fourth whorl.

Brown above, with 8 light streaks on the neck in front and 7 behind, these streaks more indistinct on the body; series of black spots between them on the sides; belly whitish.

Measurements, in Millimetres.

| | |
|---------------------------------|----|
| From end of snout to vent. | 48 |
| From end of snout to fore limb. | 17 |
| Head. | 11 |
| Width of head. | 7 |
| Depth of head. | 6 |
| Fore limb. | 15 |
| Hind limb. | 27 |
| Foot. | 15 |

The single specimen, a female from Eldorado, is preserved in the Kimberley Museum.

This species is very closely allied to *L. johnstonii*, Blgr., from Nyassaland, altitude 2000 metres, which differs chiefly in the narrower head, the longer parietal shields with concave outer border, and more numerous scales (50 to 52 across middle of body). *L. johnstonii* was the southernmost species of the genus, the range of which extends to the Soudan, Arabia, Asia Minor, and Mesopotamia.

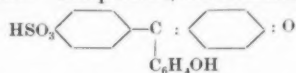
COLOUR AND CHEMICAL CONSTITUTION.

PARTS V AND VI.

By JAMES MOIR, M.A., D.Sc., F.I.C.

PART V.—THE YELLOWNESS OF CERTAIN PHTHALEINS WHEN ACID.

Attention has already been called to the fact that phenolsulphonephthalein, which is constitutionally an orthosulphonic acid of benaurine, resembles the latter substance in being yellow when neutral or slightly acid, whereas phenolphthalein is colourless under the same circumstances, although it also is an ortho-acid of benaurine. Two more examples of yellow derivatives of benaurine have now been investigated. The first is benaurine-parasulphonic acid, which is one of the products obtained when benzaldehyd is condensed with phenol and sulphuric acid at a fairly high temperature, benaurine being first formed by oxidation of leucobenaurine $C_6H_5 \cdot CH(C_6H_4OH)_2$, and subsequently sulphonated. The product, the constitution of which is—

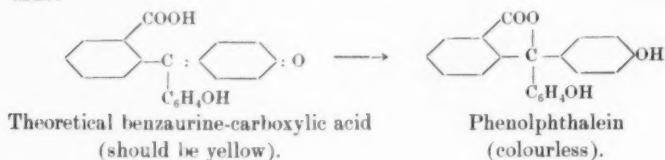


is yellow when slightly acid. It is salmon-pink in fairly strong acid, the band-centre of its absorption being at λ 512 (value for benaurine λ 507). It is violet in alkali, with band-centre about λ 568 (the value for benaurine is λ 570 with weak alkali, increasing to about λ 580 in concentrated alkali). Its behaviour is very similar to that of phenolsulphonephthalein (acid band λ 507, neutral only violet absorption, alkali band λ 563), and as the new substance is obviously not a phthalein it becomes a fair inference that phenolsulphonephthalein also is not a phthalein either, in other words the ortho — SO_3H group of the latter compound never joins up with the central carbon, for if it did the product would be a colourless non-quinonoid lactone like phenolphthalein. This difference is, of course, due to the high ionisation of all sulphonic acids. Phenolsulphonephthalein, then, should be re-named benaurine orthosulphonic acid.

The third of these yellow compounds is phenolphthalein-monomethyl ester, first described by A. G. Green and King (*Berichte*, 1907, 3727). This also resembles benaurine closely, being yellow when neutral or faintly acid, salmon-pink in acid, and violet-pink in alkali. The acid solution very

easily goes colourless through hydrolysis to ordinary phenolphthalein and possesses a broad absorption band, with its centre about λ 523. The behaviour towards alkali differs in two respects from that of phenolphthalein: (1) It is coloured by bicarbonates, phenolphthalein remaining colourless; the colour is violet-pink with band-centre at λ 560 (phenolphthalein λ 554): (2) the colour is not bleached and the substance is *not* easily hydrolysed by strong alkali; the shade becomes rather more violet and the band centre moves to λ 567 (*cf.* similar behaviour of benaurine).

Altogether, therefore, the three yellow substances very closely resemble benaurine, and, in fact, their spectra are the same as that of benaurine with the band slightly moved towards the red by "loading" with the respective substituent groups (*viz.* para - SO_3H , ortho - SO_3H , and ortho - CO.OCH_3 respectively)—a phenomenon already discussed in Part I in connection with the derivatives of ordinary phenolphthalein. It follows, therefore, that the yellow colour is the normal phenomenon, since it occurs in the parent substance benaurine itself, and is due to the quinonoid linkage in benaurine when formulated as mono-para-oxyfuchson (phenylphenol methylene-quinone). The colourlessness of phenolphthalein is abnormal in this sense, being due to a tendency to ring-formation with the central carbon-atom thus:



PART VI.—THE ULTRA-VIOLET SPECTRA OF THE PHTHALEINS.

At the end of Part I, read in March, 1917, I indicated that I suspected the phthalein bands seen in H_2SO_4 solution to be due to the "loading" with H_2SO_4 of bands in the ultra-violet, which thus were brought into the visible spectrum, and in Parts III and IV, I showed that by using a strong solution of alkaline phenolphthalein its suspected ultra-violet band could be so broadened that a portion of it became visible between λ 360 and λ 400; also that in the case of otherwise loaded phthaleins, like thymolphthalein, the low-violet bands are easily visible generally round about λ 400.

It gives me, therefore, great pleasure to announce that my observations have been confirmed and extended by photographic means in America. Hitherto I have only had access to an abstract of the new work (H. E. Howe and K. S. Gibson, of Cornell University, 'Physical Review,' 1917, p. 767), but two new ultra-violet bands of alkaline phenolphthalein are described, lying at λ 370 and 277, and, in addition, the American authors' measure-

ment of the visible band (at λ 554 or λ 555) is the same as mine. It should be noted that these wave-lengths are exactly in the ratio $\frac{1}{2} : \frac{1}{3} : \frac{1}{4}$, consequently, (1) the real *fundamental* absorption of alkaline phenolphthalein lies in the infra-red, at wave-length λ 1109 (frequency 9.02); (2) the visible band in the green is its first harmonic (λ 554, frequency 18.05); (3) the barely visible band in the extreme violet is its second harmonic (λ 370, frequency 27.07); and the band of λ 277, frequency 36.1, is its third harmonic.

In the case of a higher phthalein (presumably thymolphthalein, etc.) the same frequency-ratio of 2 : 3 : 4 was observed, the wave-lengths being about λ 626, λ 417 and λ 313, thus fully confirming my observations about the effect of "loading" of the molecule. Solutions in alcohol were found to have higher wave-lengths for the bands than similar solutions in water (the difference is plainly visible to the naked eye): alkaline phenolphthalein, which has λ 554 in water, has its band-centre at about λ 562 in alcohol, whilst in alcohol-ether (equal volumes) the band-centre is at λ 567, with quite a violet-pink tinge. This is evidently a "loading" phenomenon exactly similar to that caused by substitution in the molecule: thus alkaline phenolphthalein in alcohol-ether has nearly the same spectrum as alkaline (di)orthocresolphthalein in water. By using isoamyl alcohol containing 1 per cent. of ethyl alcohol as the solvent the band of alkaline phenolphthalein is moved up as far as λ 572, and no doubt if a suitable solvent of higher molecular weight could be found it would be possible to cause alkaline phenolphthalein to exhibit a blue colour. For example, sodium *o*-cresolphthalein, which is red-violet in water (λ 570 for centre of absorption), becomes blue-violet in amylalcohol (λ 587 for centre).

The definite discovery of these upper-harmonic ultra-violet bands in the spectra of the phthaleins has a marked value in unifying and simplifying the whole field of the research. For example, in Part I a mathematical formula was developed whereby the absorption-band (and colour) of a phthalein dissolved in conc. H_2SO_4 can be calculated from the data given by the same phthalein in alkali—wherein it has a different colour. It was also remarked at that time how anomalous it is that "loading" with H_2SO_4 increases the frequency. If now, however, we realise that the H_2SO_4 band is not the visible alkali band loaded, but is the *invisible* band loaded, the anomaly disappears. To take the simplest case, the visible band of alkaline phenolphthalein is at λ 554 in the green, whereas the visible band of phenolphthalein in H_2SO_4 is at λ 499. Now "loading" the molecule in all other cases *increases* the wave-length (diminished frequency), so if we simply assume that the λ 499 band is the λ 370 band "loaded" everything becomes consistent.

The mathematical formula given in Part I was $y = \frac{3}{2}(x - 4.6)$, in which x is the (visible) alkali frequency and y the H_2SO_4 frequency of the same phthalein. The new mathematical formula is much simpler. Since the

wave-length of the *violet* absorption band is $\frac{2}{3}$ of that of the visible one the formula becomes simply $y = x - 7$, where y is the visible H_2SO_4 frequency, and x is the violet alkali frequency. Thus for phenolphthalein x is 27.03 (viz. $10,000 \div 370$), whence y (calculated) is 20.03 (observed $10,000 \div 499$ or 20.04). For thymolphthalein $x = 25.13$ ($10^4 \div \frac{2}{3}$ of 597), whence y (calculated) is 18.13 (observed 18.18). The formula is probably rigorously exact, but the observations are not capable of a higher accuracy than, say, 0.2 per cent. The constant 7* in the formula represents the "loading" of the molecule with the constant molecular weight of H_2SO_4 , or more probably the constant atomic-volume of that substance as suggested in Part I. The following table indeed shows that the phenomena do not follow the molecular *weights*, and consequently that the atomic *volumes* are probably the cause of the position of the absorption-band in each case.

| Name. | Position of violet alkali band. | Molecular weight. | Position of band in H_2SO_4 . | M.W. of oxonium sulphate. | Law. |
|-----------------------------|---------------------------------|-------------------|---|---------------------------|---|
| Phenolphthalein | λ 370 | 318 | λ 499 | 416 | $10^4(\frac{1}{318} - \frac{1}{416}) = 7$ |
| α -naphtholphthalein | λ 441 | 418 | λ 635 | 516 | $10^4(\frac{1}{418} - \frac{1}{516}) = 7$ |
| Thymolphthalein | λ 398 | 430 | λ 550 | 528 | $10^4(\frac{1}{430} - \frac{1}{528}) = 7$ |
| Tetridophenolphthalein | λ 391 | 822 | λ 537 | 920 | $10^4(\frac{1}{822} - \frac{1}{920}) = 7$ |

The physical interpretation of this is that the frequency 27 of phenolphthalein belongs to the : C : O group of the quinonoid part (or to its divalent ion, seeing that it is a sodium salt, viz. : C $\begin{smallmatrix} \text{O}^- \\ \diagup \\ \text{O}^- \end{smallmatrix}$ + 2 Na⁺). In H_2SO_4

the configuration is : C $\begin{smallmatrix} \text{OH} \\ \diagup \\ \text{SO}_3\text{H} \end{smallmatrix}$, and this change, in *all* the phthaleins, lessens

the frequency by 7. The particular value 27 belongs to the CO group as affected by the rest of the molecule (viz. $\text{C}_{19}\text{H}_{14}\text{O}_3$). If the rest of the molecule is expanded by addition of C_6H_4 as in naphtholphthalein, the frequency goes down in the same way as it does with H_2SO_4 , but, as the Table shows, this addition of molecular weight 100 produces far more effect than the substitution of four iodine atoms (increase in molecular weight 504).

* 6.95 is perhaps a more exact value.

COLOUR AND CHEMICAL CONSTITUTION.

PART VII.—SPECTRA OF SOLID COMPOUNDS OF COBALT, NICKEL,
MANGANESE, AND URANIUM.

BY JAMES MOIR, M.A., D.Sc., F.I.C.

The main result of the earlier part of this work is the demonstration of the fact that simple coloured substances can have their colour altered by "loading" the molecule either internally or by combination with a non-ionising solvent. This phenomenon being very regular in the organic field, it became of interest to see whether it could be traced in the coloured compounds of such metals as give derivatives possessing a definite spectrum. Cobalt was first chosen because the striking spectrum of cobalt-glass suggested that non-ionised cobalt compounds would all have characteristic spectra.

I. SPECTRA OF THE COMPOUNDS OF COBALT.

The spectrum of cobalt salts dissolved in water is not striking; it is the same for all salts when a dilute solution is examined in a thick layer, and consists of a single very broad indefinite band with its centre near λ 495, this being due to the hydrated cobalt ion. Examination of partly non-ionised cobalt solutions in thin layers of strong solutions show small differences due to partial combination with the salt ion, this leading to a higher molecular weight or volume and therefore to a "loaded" vibration with higher wave-length. The centre of the broad band is near λ 505 for both the chloride and nitrate and near λ 510 for the acetate when a strong solution is examined in a thin layer. When the nitrate is fused without the addition of water the band-centre is raised to λ 510, which thus appears to be the wave-length of $\text{Co}(\text{NO}_3)_2 \cdot 6\text{Aq}$ in the non-ionised condition.

Solution of CoSO_4 in hot conc. H_2SO_4 is blue, with the band-centre raised as high as λ 575; on cooling this turns pink and has the band at λ 545. On the loading hypothesis the latter is probably due to $\text{Co}(\text{HSO}_4)_2$ and the blue form to a compound of this with H_2SO_4 . The change of pink cobalt compound to blue by heat is a general phenomenon (whether

water is present or not), and appears to be due to increase of molecular weight or volume by combination with the environing molecules. Curiously enough the nitrate and fluoride form exceptions and scarcely change at all with heat; and cobalt glass and cobalt phosphate would probably be pink at low temperatures. Some examples of this change from pink to blue may now be discussed.

a. Cobalt chloride, which in dilute solution shows the ion band at λ 495, in the solid state has the band shifted a little higher but of the same character. If the solution is boiled or treated with a little HCl two remarkable *very narrow* bands develop in the orange and the solution becomes violet. These bands are at $\lambda\lambda$ 607 and 621. Further addition of HCl, probably leading to the formation of HCoCl_3 , causes the solution to turn blue, when the original band at about λ 505 disappears and a very strong absorption with centre at λ 700 in the far red comes up, accompanied by another of centre λ 661 and a faint one at λ 640. In intermediate stages all five bands are visible, viz. the three just mentioned and the hair lines at $\lambda\lambda$ 607 and 621. When a trace of cobalt salt is dissolved in a large excess of conc. HCl the solution is greenish-blue (quite a sensitive test for cobalt), and the spectrum shows the bands at $\lambda\lambda$ 661 and 700 coalesced into one band going from λ 655 to λ 705, *i. e.* starting at the C line of the sun and going half-way to the red end. Probably it is H_2CoCl_4 which gives this spectrum. This band is of course wider if strongly-coloured solutions are used and a sixth band near λ 530 then appears.

b. Cobalt bromide does not change appreciably with heat or with considerable additions of HBr, but if dissolved in HBr (1.38 sp. gr.) and then heated the pink solution turns green, and this does not go back at once on cooling. The spectrum of the green solution is remarkable, consisting of four bands in the red, viz. a pair at $\lambda\lambda$ 637 and 662 (probably due to HCoBr_3 , since they are narrow and analogous to those attributed to HCoCl_3 at $\lambda\lambda$ 607 and 621), and a pair of broader strong bands with centres at $\lambda\lambda$ 694 and 735, probably due to H_2CoBr_4 (*cf.* $\lambda\lambda$ 661 and 700 in H_2CoCl_4). In deeply-coloured solutions the whole red end from λ 680 to λ 760 is absorbed. The band at λ 735 is a most exceptional one, being, I think, the only known narrow absorption-band in the far red in any substance; direct sunlight or similar intense light is necessary to enable it to be seen, and a violet filter should be used to protect the eye from the glare of the adjacent orange light.

c. Cobalt iodide changes from pink with the utmost difficulty, but a yellow-green film was obtained on drying an HI solution of CoI_2 , which had a marked band at λ 694. This probably corresponds to HCoI_3 and to λ 621 in HCoCl_3 and λ 662 in HCoBr_3 . A very dark brown, practically opaque, phase is produced on further drying, which could not be obtained thin enough for spectroscopy.

d. Cobalt-glass and its analogues.—This blue glass has three marked absorption-bands with centres at $\lambda\lambda$ 541, 589 and 652. The spectrum of the *cobalt borax-bead* is similar, but the bands are lower down (mol. wt. of cobalt borate less than that of cobalt silicate), the centres being at $\lambda\lambda$ 527, 577 and 641. A third spectrum of this class is given by cobalt dissolved in hot fused metaphosphoric acid ($\text{Co}(\text{PO}_3)_2$ in HPO_3) which has band-centres at $\lambda\lambda$ 533, 582, and about 640. This turns pink on cooling and loses the spectrum just described. The middle band is much stronger than the others in all cases. The blue solution of cobalt in very strong potash, containing $\text{Co}(\text{OK})_2$, gives a fourth spectrum of this class, the centres being at $\lambda\lambda$ 530, 579 and 638. The purple solution from cobalt, potash and sugar contains only two bands, the chief one being at λ 592, the other, at λ 490, being probably only that of cobalt hydrate. If glycerol be used instead of sugar the solution is blue and the bands are at $\lambda\lambda$ 585 and 640, *i. e.* very like the glass. Cobalt ammonium phosphate in ammonia is purple and the bands are at $\lambda\lambda$ 598 and 629.

Another and more remarkable blue cobalt solution is the double potassium sulphocyanide K_2CoScy_4 . This, when extracted into alcoholic ether, has sharp bands at $\lambda\lambda$ 579 and 621, and when in amyl alcohol or amylacetate has the bands at $\lambda\lambda$ 581 and 626.

The cobaltammines with trivalent cobalt have no characteristic spectra.

II. SPECTRA OF THE NICKEL COMPOUNDS.

Although nickel chloride gives a characteristic spectrum, none of the other compounds show anything definite. This is probably because the effect of loading the molecule is to shift the absorption-bands right off the spectrum. $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ has two absorption-bands with centres at about $\lambda\lambda$ 652 and 690 and a strong narrow transmission between them (at about λ 675). This transmission survives in strong solutions in which the bands have broadened so as to cut off nearly all the rest of the red.

III. THE SPECTRUM OF THE PERMANGANATES.

Dilute solutions of permanganates, it is well known, give an absorption-spectrum containing five bands which appear to be equally spaced. Two of these, the second and third, are much stronger than the others, and by using stronger solutions the author has been able to observe two more farther down in the violet, making seven bands in all. The author has also succeeded in expressing their rhythmic character by a mathematical formula,

viz. $\lambda = \frac{10^7}{1750 + 78 N}$, which, by taking N to be successively 0, 1, 2, 3, 4, 5, and 6, gives seven values of λ agreeing within experimental error with the

observed wave-lengths of the absorption-centres, viz. 572, 547, 525, 504, 485, 468 and 451 (observed 572, $546\frac{1}{2}$, $524\frac{1}{2}$, 503, 486, 469 and 454). The reflection spectrum of solid KMnO_4 contains emission-bands at 577, 552, 530, etc., which evidently correspond to the non-ionised KMnO_4 of slightly higher molecular weight or volume than the ion MnO_4^- to which the ordinary absorption bands belong.

IV. SPECTRA OF URANIUM COMPOUNDS.

The uranyl compounds in solution exhibit a spectrum which is a sort of imitation or continuation of the permanganate spectrum, consisting of five bands equally spaced in the blue. For the UO_2^{++} ion (thick layer of dilute solution) the positions of the five absorption-centres are $\lambda\lambda$ 473, 459, 446, 433 and 420, the central one being strongest. The effect of "loading" was studied by examining *solid* uranium salts by transmitted light, excluding fluorescence by means of a black cover. Uranyl acetate (+3Aq) gave the readings $\lambda\lambda$ 476, 464, 445, 432 and 422. Basic uranyl acetate (orange) gave $\lambda\lambda$ 487, 471, 459, 449 and 440. Hydrated uranyl chloride gave only $\lambda\lambda$ 483 and 467. Hydrated uranyl nitrate gave $\lambda\lambda$ 486, 469 and 455, which remained unchanged even after melting the crystals and heating for some time.

Uranyl bisulphate in conc. H_2SO_4 (strong thin layer) and uranyl metaphosphate in HPO_3 both had the same four bands, at $\lambda\lambda$ 492, 475, 458 and 438; uranyl perchlorate in conc. HClO_4 had the bands at $\lambda\lambda$ 488, 471, 456 and 443; in the solid state this substance gave bands at about $\lambda\lambda$ 506, 490 and 470, and possibly a higher and a lower one; finally, solid natural autunite (from Madagascar*) gave $\lambda\lambda$ 514 faint, 500, 485, 470 and 456.

The latter two show great loading effect as a result of their much greater molecular size, and, speaking generally, the change in position of the bands follows the molecular weight qualitatively though not proportionally.

In fact, the change in wave-length appears all through to be roughly proportional to the 6th root of the molecular weight. Thus for autunite, as compared with the ion UO_2^+ , the ratio of the molecular weights is $\frac{914}{540}$, of which the 6th root is 1.091: now the five ratios $\frac{514}{473}$, $\frac{500}{459}$, $\frac{485}{446}$, $\frac{470}{433}$ and $\frac{456}{420}$ have all an average of 1.089 within the experimental error.

A similar state of affairs holds for uranyl perchlorate if we assume one mol. of Aq. and make the line λ 506 correspond with the *second* line of UO_2^{++} , viz. 459: the ratios of all the lines agree with the 6th root of the ratio of the molecular weights.

* $\text{Ca}(\text{UO}_2\text{PO}_4)_2 \cdot 8\text{Aq.}$

† Multiplied by 2.

In the case of cobalt the homologous lines $\lambda\lambda$ 621, 662 and 694, seen respectively in the acid chloride, bromide, and iodide, have ratios which are almost exactly the same as the 8th root of the ratios of the molecular weights.

In the phthaleins, where the substituents are singly-linked carbon atoms, it is the 4th root of the ratio of the molecular weights which agrees with the ratio of the absorption wave-lengths, but the halogen-derivatives do not follow this rule.

I do not yet know if it is more than a coincidence that these roots, 6, 8 and 4, are the same as the valencies (periodic place) of uranium cobalt and carbon.

NOTE ON URANOUS (TETRAVALENT) COMPOUNDS.

These are blue-green and have a striking spectrum. The band-centres of the U^{++++} ion are: $\lambda\lambda$ 688 and 673 (hair-lines), 650 (very strong), 553, 496 and 440. $U(PO_3)_4$ in solid HPO_3 has the bands $\lambda\lambda$? 700, 689, 670 (strong), 629, ? 580 and 545.

COLOUR AND CHEMICAL CONSTITUTION.

PART VIII.—FLUORESCENCE AND ITS LAWS.

BY JAMES MOIR, M.A., D.Sc., F.I.C.

While engaged in investigating the absorption-spectra of uranium compounds (see Part VII), I noticed that the green fluorescence which they mostly exhibit had a very definite emission-spectrum of 4 or 5 nearly equally spaced bands of about the same breadth as the bands (in the blue) of the absorption-spectrum. This phenomenon has been known for a long time in the case of uranium glass, but I think it is generally believed that all uranium compounds give the same fluorescent spectrum, which is not the case.

It is true that all aqueous uranium solutions, which by the way are devoid of fluorescence, if examined in a thick layer of dilute solution, give the same absorption-spectrum, this spectrum being due to the ion UO_2^{++} . The differences are only shown when there is *no* ionisation, *i. e.* in the solid state or in non-aqueous solution—and in such case there is generally a fluorescence.

The following are the positions of the centres of the bands in these emission-spectra of fluorescent uranium compounds:—

- (1) *Uranyl nitrate crystal*: $\lambda\lambda$ 560, 535, 510 and 485 (vague).
- (2) *Uranyl acetate crystal* (yellow): only one bright band, at about λ 525.
- (3) *Basic uranyl acetate* (orange): $\lambda\lambda$ 560 (vague), and 536 and 511.
- (4) *Autunite* (calcium uranyl phosphate): $\lambda\lambda$ 575, 554, 529 and 508.
- (5) *Uranyl bisulphate* (in H_2SO_4): $\lambda\lambda$ 565, 541, 514 and 492.
- (6) *Uranyl metaphosphate* (in HPO_3 solid): $\lambda\lambda$ 590, 566, 542, 515 and 495.
- (7) *Uranyl sodium metaphosphate* (microcosmic bead): $\lambda\lambda$ 602, 562, 543 and 517.

(8) *Solid uranyl chloride* had a fluorescence too faint to observe.

As will be seen on examining these figures, the bands are equally spaced or rhythmic: probably there are always five of them, but some are too faint to observe, and it is not always the same one in the order which is the brightest. It is therefore rather difficult to correlate them, but I have succeeded in finding a remarkable numerical relationship between the wavelength of any fluorescent band and that of the absorption-band which

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As will be seen on examining these figures, the bands are equally spaced or rhythmic: probably there are always five of them, but some are too faint to observe, and it is not always the same one in the order which is the brightest. It is therefore rather difficult to correlate them, but I have succeeded in finding a remarkable numerical relationship between the wavelength of any fluorescent band and that of the absorption-band which

(presumably) gave rise to it. For example, if we confine our attention to the band of second highest wave-length, we find that the fluorescent light has a wave-length which is 1.14 times the wave-length of the second line in the absorption-spectrum, and this figure holds for all the substances. For uranyl nitrate the fluorescent line is λ 535 and the absorption line λ 470; for basic uranyl acetate the respective figures are λ 536 and λ 471; for autunite the figures are λ 554 and λ 485; for uranyl bisulphate they are λ 541 and λ 475; and for the metaphosphates (acid and sodium) the ratios are 542/475 and 562/492. These ratios vary only between 1.139 and 1.142, which is purely experimental error.

Again, if we confine our attention to the first band in each substance, the constant ratio for all the substances is again met with, but this time it is 1.150: the particular cases are: uranium nitrate 560/486, uranium bisulphate 565/492, autunite 575/500, uranyl acid metaphosphate 566/492, the variation in the ratio being from 1.149 to 1.151.

For the third band there is again a constant ratio, the value of which is about 1.119, and for the fourth band, which is, however, not accurately observable, the value of the constant ratio is about 1.110.

The fact that these four ratios should themselves be so close together and yet be undoubtedly different for each of the four corresponding lines is in itself very remarkable. At first sight one would suppose that the ratio represents the ratio of two adjacent natural numbers, *e.g.* 8/7, on the supposition that the fluorescent light is the seventh harmonic of a fundamental of which the absorbed light is the eighth harmonic. As will be seen above, the fluorescence phenomenon is independent of the size of the molecule, the ratio being the same for all the substances. It may next be noted that the change in ratio from the fourth to the first line is about 1 part in 29, whereas the corresponding change in wave-length, *e.g.* 575 to 500 in autunite, is about 1 part in 7, so that it appears that the value of the ratio varies according to the fourth root of the fluorescent wave-length. Thus $1.15 \div 1.11 =$

1.036, whilst the value of $\sqrt[4]{\frac{575}{500}}$ is 1.036. Again, the values for the other

substances are: $\sqrt[4]{\frac{560}{485}} = 1.036$ (nitrate); $\sqrt[4]{\frac{565}{492}} = 1.035$ (bisulphate);

$\sqrt[4]{\frac{566}{495}} = 1.034$ (metaphosphate). It becomes thus possible to show that

any fluorescent line can be directly calculated from an observation of the position of any other fluorescent line along with an observation of the corresponding absorption line.

The equation $\frac{A_s}{A_t} = \left(\frac{F}{F_t}\right)^4$ holds true for all the lines, in which A_s and F are corresponding wave-lengths in the absorption and in the fluorescent

spectrum, and A_l and F_l the wave-lengths of the lowest band in the two spectra respectively. Thus in uranyl metaphosphate the lowest fluorescent band is at $\lambda 495 = F_l$. Now suppose that the *absorption* spectrum shows a band at $\lambda 460 = A$, and a last band at $\lambda 446 = A_l$. The value of $\frac{A_n}{A_l}$ is

1.031, and this, raised to the $4/3$ power, gives the value of $\frac{F_n}{F_l}$, viz. 1.042.

Hence F_n calculated is $515\frac{1}{2}$: the observed value was 515. Expressed in words, the equation means that the cube of the fluorescent wave-lengths varies as the fourth power of the absorption wave-lengths, or that the cube of the ratio of two fluorescent frequencies is equal to the fourth power of the ratio of the corresponding absorption frequencies. If we employ a constant to eliminate the necessity for an observation of the lowest wave-length the formula becomes:

$$F_n = 0.145 (A_n)^{\frac{4}{3}} \text{ (three figures only in wave-length reading).}$$

Thus if there is an absorption band at $\lambda 499$, $A_n = 499$, and F_n is $0.145 \times 499 \times 7.93 = 574$. This gives the central wave-length of the fluorescence. What the physical basis of this may be in terms of light-waves and periodic time of electrons I must leave to physicists to elucidate. Meanwhile I may point out that the ratio of fluorescent emission to absorbed wave-length is much the same amongst organic compounds, viz. about 1.15 for both fluorescein and rhodamine, so that the law appears to hold for many substances other than uranium compounds.

A POSSIBLE LUNAR INFLUENCE UPON THE VELOCITY OF THE WIND AT KIMBERLEY.

By J. R. SUTTON, M.A., Sc.D., F.R.S.S.A., Hon. Memb. R. Met. S., Hon.
Memb. S.A.S.C.E.

The object of the present discussion is to determine whether there is a lunar term in the velocity of the wind at Kimberley. A test investigation made on a small scale some years ago established the possibility of such a term; but it is obvious that definite proof of the same could only be furnished from the results of a long series of observations. Because, for one thing, any share of the movement of the air which can depend upon any conceivable lunar influence must be a very small fraction of the share depending upon recognised meteorological factors; and hence our discussion must be on such a scale as will afford a reasonable guarantee that the effects of ordinary meteorological irregularities are lost in the mass.

Reasoning *à priori*, a lunar term in the velocity of the wind should be expected. If the moon can generate and maintain a tide in the atmosphere, as we know it does, it must also be able, directly or indirectly, to raise the wind. The only question would seem to be whether it can raise it to a measurable amount, and how. The lunar atmospheric tide at Kimberley is of the order '003 inch in amplitude with very little establishment. Hence, since the diurnal, thermal, variation of barometric pressure at Kimberley has a range of about '09 inch (*i. e.* thirty times the lunar tide), corresponding to a range of wind velocity of about 3·4 miles an hour, we should expect, for the sake of argument, a lunar variation in the velocity of the wind of about $3\cdot4/30$ ($= 0\cdot11$) miles an hour. We shall see presently that, if the observations are accounted adequate to prove the case, this estimate is too low.

The Kimberley register contains hourly values of the velocity of the wind since 1897, with only an occasional break. The site of the anemometer is none of the best, though perhaps good enough to give a negative or affirmative answer to the simple question whether the moon is of any account at all in the matter of the wind. The automatic records of velocity are easily read to one-tenth of a mile an hour. The average velocity of the wind at Kimberley is in the neighbourhood of five miles an hour, rising occasionally to more than thirty.

For the purposes of this discussion the hourly velocities in the Kimberley register have had to be rearranged in terms of the lunar day. This has been done by arranging the hourly velocities in twenty-five columns, the middle column, containing the velocity for the hour in which the moon made its upper meridian passage (U.M.P.), being accounted lunar noon, the mean of the first and twenty-fifth columns being accounted lunar midnight (L.M.P.).

In the table below, column 1 indicates the hours and column 2 the mean hourly velocities for those hours for the 180 lunations = (5135 lunar days) from April, 1897, to October, 1911. There were two gaps in the period, when the anemometer had to be dismounted for repairs—one, from September 24 to October 8, 1908, being filled up from values obtained during September 26 to October 10, 1916; the other, from July 9 to 23, 1911, being filled up from values obtained during July 13 to 27, 1916.

According to column 2, the curve purporting to show the lunar effect on the velocity of the wind has only one definite maximum and minimum, the former falling about three hours before lunar midnight, the latter about an hour before lunar noon, the range being 20 miles an hour.

Column 3 shows the result for the 2538 days of the period when the moon was south of the equator, and column 4 the result for the 2597 days when the moon was north.

The general inference from column 3 is a maximum velocity near lunar noon and a minimum near midnight, with a range of 32 miles an hour; whereas column 4 gives almost exactly the opposite tendency with a range of 55 miles an hour. These ranges are considerably greater than one would have expected to find. The lesser range for the time when the moon is south is probably partly due to the small secondary minimum shown in column 3 at lunar noon.

If the variations of velocity shown in the table are to be regarded as entirely due to the lunar atmospheric tide, it is not easy to explain why column 2 shows only one maximum and minimum in the lunar day, especially as a preliminary investigation of the variations of velocity at perigee suggests a strong semidiurnal oscillation, with maxima at lunar moon and midnight, and minima near moonrise and moonset. This point, however, is reserved for treatment at some later time. Meanwhile it is easy to see that if, when the moon is in north declination, there is only one maximum of velocity in the lunar day, and that synchronising with the lower meridian passage, there should be, when the moon is in south declination, only one maximum, and that synchronising with the upper meridian passage. For the maximum aerotidal effect of the moon's action is felt in the southern hemisphere near the antipodes of the sub-lunar point when the moon is in the north, and near the sub-lunar point itself when the moon is in the south. In this connection it is worth notice that when the moon's declination, north or south, is greatest, the semidiurnal lunar atmospheric tide at Kimberley practically disappears, resolving itself into a single oscillation, the phase when the moon is north being nearly the reverse of that when the moon is south.*

The results given in this paper throw no light apparently on the possible

* Corresponding to this diurnal inequality there are indications of an atmospheric swell following the moon to and fro across the equator.

variations of evaporation and rainfall during the course of the lunar day discussed in a recent paper.*

[*Note*.—My wife, without whose help the great labour of the above investigation could not have been undertaken, has kindly checked the averages given in the table.]

Table showing the Variation and Wind Velocity in Miles an Hour during the Course of the Lunar Day.

| Hour. | Mean. | Moon south. | Moon north. |
|--------|-------|-------------|-------------|
| L.M.P. | 5.29 | 5.18 | 5.39 |
| II | 5.23 | 5.17 | 5.30 |
| III | 5.25 | 5.21 | 5.29 |
| IV | 5.26 | 5.26 | 5.26 |
| V | 5.24 | 5.23 | 5.24 |
| VI | 5.20 | 5.24 | 5.15 |
| VII | 5.21 | 5.29 | 5.14 |
| VIII | 5.22 | 5.33 | 5.12 |
| IX | 5.20 | 5.37 | 5.03 |
| X | 5.20 | 5.43 | 4.98 |
| XI | 5.16 | 5.39 | 4.94 |
| XII | 5.15 | 5.37 | 4.94 |
| U.M.P. | 5.16 | 5.38 | 4.93 |
| XIV | 5.22 | 5.44 | 5.01 |
| XV | 5.22 | 5.41 | 5.05 |
| XVI | 5.27 | 5.40 | 5.14 |
| XVII | 5.30 | 5.40 | 5.19 |
| XVIII | 5.32 | 5.40 | 5.25 |
| XIX | 5.31 | 5.29 | 5.33 |
| XX | 5.29 | 5.19 | 5.39 |
| XXI | 5.34 | 5.21 | 5.46 |
| XXII | 5.35 | 5.23 | 5.46 |
| XXIII | 5.30 | 5.12 | 5.48 |
| XXIV | 5.33 | 5.19 | 5.46 |
| L.M.P. | 5.31 | 5.22 | 5.40 |

ADDENDUM.

Column 2 may be represented pretty closely by the formula—

$$\begin{aligned}
 V = & 5.25 + .075 \sin (138^{\circ}.4 + n 15^{\circ}) \\
 & + .019 \sin (264^{\circ}.5 + 2n 15^{\circ}) \\
 & + .013 \sin (123^{\circ}.0 + 3n 15^{\circ}) \\
 & + .044 \sin (183^{\circ}.8 + 4n 15^{\circ}) \\
 & + \dots
 \end{aligned}$$

The relative magnitude of the fourth harmonic term is remarkable. It gives maximum values at 0430, 1030, 1630, and 2230 of lunar time. The second harmonic term gives maxima about 0600 and 1800.

* J. R. Sutton, "A Possible Lunar Influence upon Evaporation and Rainfall," *Trans. Roy. Soc. South Africa*, 1918.

HAEMOLYSIS BY SERUM IN COMBINATION WITH CERTAIN BENZOL BODIES.

By T. J. MACKIE.

While serum-complement acts as haemolysin in the presence of a specific immune body, and also along with colloidal silicic acid (Landsteiner and Jagic, Browning and Mackie), serum is also capable of producing lysis of red blood-corpuscles which have been treated with certain benzol bodies (Mackie (1), Browning and Mackie (2)).

In the original experiments it was found that if rabbit's corpuscles in suspension were treated with minute quantities of tetra-ethyl-diamino-triphenyl-methane sulphate (brilliant green) and then rabbit's serum in certain amounts was added, rapid haemolysis ensued. The amounts of brilliant green used were quite non-haemolytic by themselves. Table I shows the result of such an experiment. Even larger quantities of the dye are capable of producing only partial haemolysis by themselves, and amounts of serum which are insufficient to accelerate lysis with these quantities of brilliant green actually inhibit the haemolytic action of brilliant green by itself. An amount of brilliant green equal to ten times the smallest quantity necessary to produce lysis in the presence of serum produced only half-lysis of the test suspension, and that only after two hours' incubation at 37° C., while the same quantity of brilliant green in the presence of 0.1 c.c. of serum produced no effect. The lysis by brilliant green and serum was found to have attained its maximum in about a quarter of an hour even at room temperature.

Ox's corpuscles were found to be practically insusceptible to brilliant green by itself unless in large amounts, and in the presence of minute quantities of the dye rabbit's serum was capable of producing lysis of these corpuscles (Table II).

This effect, unlike haemolysis by serum + colloidal silicic acid, is not due to complement, since serum which has been heated at 55° C. for one hour, and serum from which complement has been removed by treatment with sensitised stomata or by cobra-venom (Omorokow's method), is as active as fresh serum (Tables III and IV).

As in the case of haemolysis by serum + colloidal silicic acid, "zone phenomena" are noticed (see Tables I, II, IV); thus there is an optimum

amount of brilliant green in the presence of which the hæmolytic effect is produced with the minimum of serum.

Excess of the dye, therefore, may inhibit the action of the serum and necessitate larger amounts of serum being used to produce lysis. In fact, treatment of the serum by brilliant green before the addition of the corpuscles may abolish the hæmolytic action altogether, as shown in Table V. In carrying out these experiments, it was found that smaller amounts of serum were capable of producing hæmolysis if the corpuscles were treated with the brilliant green for about a quarter of an hour before the addition of serum. Thus a certain length of time was required for the absorption of the dye by the corpuscles and the consequent physical or chemical alterations which rendered them susceptible. If the suspension which had been treated with brilliant green was centrifugalised, it was found that the bulk of the added dye was present in the supernatant fluid, and that when this was pipetted off and the corpuscular sediment washed with salt solution several times (till the supernatant fluid showed no tinting), and then re-suspended, the cells were still susceptible to the action of serum, and smaller amounts of serum were required to produce lysis than in the case of the original suspension. A treated suspension prepared in this way showed practically no green tinting. This suspension was found to be quite stable, and did not undergo spontaneous lysis; on the addition of serum, however, almost instantaneous lysis occurred.

Table VI shows the results of an experiment in which corpuscles were treated in this way: 1 c.c. of a 0.1 per cent. solution of brilliant green was added to 10 c.c. 5 per cent. suspension of washed ox's corpuscles (*i. e.* 0.05 c.c. to 0.5 c.c. suspension). The suspension was allowed to stand at room temperature for a quarter of an hour, and was then centrifugalised; the supernatant fluid was decanted and the sediment was washed several times with 0.85 per cent. NaCl till the washing fluid showed no tinting. The sediment after the last washing was suspended in 10 c.c. 0.85 per cent. NaCl, and showed practically no green coloration. The addition to 0.5 c.c. of this suspension of 0.025 c.c. of rabbit's serum produced immediate lysis. A parallel test was made with corpuscles to which brilliant green had been added (0.05 c.c. 0.1 per cent. solution to 0.5 c.c. suspension), as in the original experiments, and after the suspension had stood at room temperature for a quarter of an hour, varying amounts of serum were added to 0.5 c.c. of the suspension. Lysis only occurred in this case with larger amounts of serum.

As a further proof of the inhibiting effect of excess of brilliant green on the hæmolytic action of the serum, an experiment was carried out in which a fixed amount of heated rabbit's serum was mixed with varying quantities of brilliant green and then red blood-corpuscles treated with brilliant green were added. The result showed that serum in the presence of excess of brilliant green was incapable of exerting its hæmolytic action (Table VII).

It has already been noted how the haemolytic action of the serum with brilliant green is not due to complement, since serum heated to 55° C. is still capable of acting. In order to ascertain whether this property was stable at higher temperature, tests were made with diluted rabbit's serum which has been boiled for two minutes. It was found that boiled serum was as active as fresh serum (Table VIII).

Rabbit's serum was also fractioned into (1) Albumin, (2) pseudo-globulin from "end-piece," and (3) "mid-piece" (by method of Browning and Mackie), and these fractions were tested separately and in combination with the treated corpuscles. As regards the haemolytic property of the serum, no qualitative fractioning occurred; all these protein fractions separately exerted a certain degree of haemolytic action which was less than that of the whole serum. When combined the full quantitative effect was reproduced, but only by "summation of effects" (Table IX).

Lecithin was also found to produce haemolysis of corpuscles treated with brilliant green (Table X).

That the haemolytic action of serum with brilliant green was not due to the action of lipoids (*e. g.* lecithin) present in it was proved by the fact that serum which had been extracted with alcohol and ether still retained its haemolytic activity (Table XI). Rabbit's serum was treated with a considerable excess of alcohol; the precipitated protein was removed by centrifugalisation and washed four times with a mixture of alcohol and ether; the precipitate was then suspended in a volume of salt solution representing five times the volume of the original serum.

Thus one must conclude that the active principle of the serum is an extremely stable one, and is resident in and distributed among the different proteins of the serum. It has been found possible to abolish the activity of the serum by filtering it through a Berkefeld filter. In this connection it is to be remembered that various enzymes are similarly retained in porcelain filters during filtration (Levy (3)), and, as Muir and Browning (4) originally showed, complement is removed from serum by the same process.

When the sera of a number of different animal species were tested with corpuscles of different species, it was found that the action of brilliant green in sensitising red corpuscles to the haemolytic effect of the serum was a general one, and there was no evidence of specificity as regards the action of any particular serum on the corpuscles of different species (Table XII). Thus brilliant green is capable of sensitising the corpuscles of an animal to the lytic action of its own serum, and the sera of the rabbit, guinea-pig, ox, sheep and man are all capable of lysing ox's corpuscles which have been treated with brilliant green to a more or less equal extent, though with some degree of variation. The lytic dose of sera of different species and of different individuals of the same species may vary from 0.005 c.c. to 0.05 c.c. The average dose of any serum may be said to be about 0.025 c.c. A

number of other substances have been tested with ox's corpuscles treated with brilliant green to ascertain whether other proteins, apart from those of serum, possess this property; varying amounts of egg albumen were added to ox's corpuscles which had been treated with different amounts of brilliant green. No haemolysis resulted. Peptone and gelatin solutions were also tested and found inactive. Other bodies which have been shown to play a part in various haemolytic phenomena were also tested. Thus varying amounts of brilliant green were added to ox's corpuscles which had been sensitised with 5 M.H.D. of a powerful haemolytic immune body (0.0025 to 1 c.c.) without effect. Colloidal silicic acid also showed no power of lysing corpuscles treated with brilliant green. The addition of varying amounts of brilliant green to venomised corpuscles also failed to produce lysis. Glucose solution had no haemolytic action on corpuscles treated with brilliant green.

Human cerebro-spinal fluid was found to be actively haemolytic to ox's corpuscles sensitised by brilliant green, though comparatively large amounts were necessary (0.1 c.c. to 0.25 c.c.); cerebro-spinal fluid was also found to have no inhibitory action on the lysis by the serum and brilliant green. Cerebro-spinal fluid heated for five minutes at 100° C. was as active as fresh cerebro-spinal fluid. This lysis occurred even when the fluid contained a minimal amount of protein, as evidenced by the absence of a precipitate or turbidity on the addition of an equal volume of 96 per cent. alcohol. These were all of course pathological cerebro-spinal fluids removed from cerebral and spinal cord cases for the Wassermann test. There was no correspondence between their activity with brilliant green and their power of reacting in the Wassermann test. Nos. 1 and 2 (Table XIII) contained small amounts of protein (shown by the alcohol test); No. 3 contained no appreciable amount of protein, and it was the most active, showing clearly that the effect does not depend on the presence of the serum proteins in the fluid. The fluid from a cystic swelling of the axilla was tested with corpuscles sensitised with brilliant green. This fluid was highly albuminous, and small quantities were sufficient to produce lysis (Table XIII). A richly albuminous urine was also tested. The albumin of 20 c.c. was precipitated by alcohol, removed by centrifugalisation, and suspended in 3 c.c. 0.85 per cent. NaCl. It was found that 0.5 c.c. of this suspension was capable of producing lysis of ox's corpuscles treated with brilliant green (Table XIV).

The susceptibility of ox's red blood-corpuscles to laking by hypotonic salt solution, acid and alkalies was investigated. Thus it has been shown that in certain pathological states, alterations occur as regards the susceptibility of human erythrocytes to various laking agents (McNeil and others) (5). It was found, however, that ox's corpuscles treated with brilliant green exhibited the same degree of susceptibility to hypotonic salt solution as normal corpuscles.

A very peculiar change was, however, noted as regards the susceptibility of the treated corpuscles to the lytic action of acid. Alkali was not, however, found to be more haemolytic than in the case of normal ox's corpuscles.

Varying amounts of $\frac{N}{100}$ HCl and $\frac{N}{100}$ NaOH were added to 1 c.c. ox's corpuscles sensitised with brilliant green, and in parallel series the same amounts were tested with 1 c.c. suspension of normal ox's corpuscles. In one experiment $0.075 \frac{N}{100}$ HCl produced lysis of the treated corpuscles, while 0.25 c.c. was required to haemolyse 1 c.c. of the untreated suspension. Thus the treated corpuscles are more than three times as susceptible to the action of acid. There is, however, no difference in susceptibility to the action of $\frac{N}{100}$ alkali.

While these experiments have been carried out with brilliant green, other allied benzol compounds have been found to behave in a similar fashion, *e.g.* diamino-triphenyl-methane-hydrochloride (Döbner's violet), tetra-methyl-diamino-triphenyl-methane (malachite green), hexa-ethyl-triamino-triphenyl-methane (ethyl violet), and hexa-methyl-triamino-triphenyl-methane (methyl violet).

It has thus been shown how serum possesses certain haemolytic properties apart from the action of the labile complement; as in the case of haemolysis by complement the serum, of course, is incapable of affecting the intact corpuscles, and just as the sensitising effect of immune body or colloidal silicic acid renders the red cells susceptible to the toxic action of the complement, so also these benzol bodies bring about some sensitisation of the corpuscles. It is impossible to say what this sensitisation depends on. It is certain that physical alterations of the stromata are produced and that these bodies have the power of slowly damaging the corpuscles, but the experiments clearly demonstrate that there is a thermo-stable property or constituent of serum concerned in affecting lysis of red blood-corpuscles, provided some preliminary physical alteration is produced. The ultimate result is not of the nature of a disintegration of the cells, since the stromata are still visible under the microscope after haemolysis, as in the case of complement-immune-body haemolysis. It is also remarkable that minute amounts of serum (*e.g.* 0.005-0.025 c.c.) are capable of lysing the treated corpuscles. While lecithin possesses similar qualities, it cannot be said that the action of the serum depends on its lipoids. Moreover, though, in the case of serum, this peculiar property is indissociable from its proteins, and may be resident in the proteins excreted in a pathological urine, it is doubtful whether it is directly attributable to them, since cerebro-spinal fluids which were practically devoid of proteins are capable of lysing the sensitised corpuscles even in comparatively small amounts.

TABLE I.

Lysis of 1 c.c. 5 per cent. Suspension Washed Rabbit's Corpuscles.

| | | Rabbit serum (same animal). | | | |
|---|-----------|-----------------------------|---------------|----------|-----------|
| | | 0.1 c.c. | 0.2 c.c. | 0.4 c.c. | No serum. |
| Brilliant green 1 per cent. aqueous solution rendered isotonic immediately before use by addition of appropriate amount of 10 per cent. NaCl. | c.c. 0.01 | 0 | Trace | Distinct | 0 |
| | 0.025 | 0 | Just complete | Complete | 0 |
| | 0.05 | 0 | 0 | Complete | 0 |

Readings after 1 hour at 37° C.

TABLE II.

Lysis of 0.5 c.c. 5 per cent. Suspension Washed Ox's Corpuscles.

| | | Rabbit serum. | | | | |
|---|------------|---------------|-----------|----------|----------|-----------|
| | | 0.025 c.c. | 0.05 c.c. | 0.1 c.c. | 0.2 c.c. | No serum. |
| Brilliant green 0.1 per cent. solution (isotonic) | c.c. 0.075 | Distinct | Complete | Complete | Complete | 0 |
| | 0.1 | " | " | " | " | 0 |
| | 0.125 | 0 | Marked | " | " | 0 |

Control: 0.5 c.c. ox's red blood-corpuscles + 0.5 c.c. rabbit serum = no lysis.

Readings after 1 hour at 37° C.

TABLE III.
Lysis of 0.5 c.c. 5 per cent. Suspension of Washed Rabbit's Corpuscles + 0.075 0.1 per cent. Solution of Brilliant Green (Isotonic).

| | Rabbit's serum. | | | | Controls. |
|---|-----------------|-----------------|----------|----------|-----------|
| | 0.05 c.c. | 0.1 c.c. | 0.2 c.c. | 0.3 c.c. | No serum. |
| Unheated serum | Very marked | Almost complete | Complete | Complete | 0 |
| Serum heated at 55° C. for 1 hour | Ditto | Complete | " | Distinct | 0 |
| Serum treated with ox's blood-corporuscle stromata + 10 doses of immune body (14 hours at 37° C.) | " | " | " | " | 0 |

0.2 c.c. serum + 0.5 c.c. 5 per cent. ox's blood + 5 doses of immune body = complete lysis.

0.6 c.c. serum + 0.5 c.c. 5 per cent. ox's blood + 5 doses of immune body = no lysis.

0.6 c.c. serum + 0.5 c.c. 5 per cent. ox's blood + 5 doses of immune body = no lysis.

TABLE IV.
Lysis of 0.5 c.c. 5 per cent. Suspension Washed Ox's Corpuscles.

| | Fresh rabbit's serum. | | | | Serum treated with cobra venom. | | | No serum. |
|---|-----------------------|-----------------|----------|----------|---------------------------------|-----------------|-----------------|-----------|
| | 0.025 c.c. | 0.05 c.c. | 0.1 c.c. | 0.2 c.c. | 0.025 c.c. | 0.1 c.c. | 0.2 c.c. | |
| Brilliant green 0.1 per cent. solution (isotonic) | 0 | Almost complete | Complete | Complete | Distinct | Complete | Complete | 0 |
| | Very marked | Complete | " | " | " | Almost complete | " | 0 |
| | Trace | Marked | " | " | 0 | Marked | Almost complete | 0 |

Controls: 0.5 c.c. ox's corpuscles + 0.5 c.c. rabbit's serum = no lysis.
 " " + 5 IB + 0.2 rabbit's serum = complete lysis.
 " " + 0.2 c.c. rabbit's serum treated with venom = no lysis.

TABLE V.

A.—0.5 c.c. 5 per cent. Suspension Rabbit's Corpuscles + 0.1 c.c. of 0.1 per cent. Solution Brilliant Green incubated together for $\frac{1}{4}$ hour at 37° C.

| + Rabbit's serum. | | | |
|-------------------|----------------|----------------|-----------------|
| 0.05 c.c. | 0.1 c.c. | 0.2 c.c. | 0.3 c.c. |
| Complete lysis | Complete lysis | Complete lysis | Complete lysis. |

B.—0.1 c.c. of 0.1 per cent. Solution of Brilliant Green + Varying Amounts of Rabbit's Serum incubated together for $\frac{1}{4}$ hour at 37° C. and then 0.5 c.c. 5 per cent. Suspension of Rabbit's Corpuscles added.

| Rabbit's serum. | | | |
|-----------------|----------|----------|-----------|
| 0.05 c.c. | 0.1 c.c. | 0.2 c.c. | 0.3 c.c. |
| No lysis | No lysis | No lysis | No lysis. |

TABLE VI.

Lysis of 0.5 c.c. 5 per cent. Suspension Ox's Corpuscles.

| | Heated rabbit's serum (55° C.). | | | | |
|---|---------------------------------|-----------|----------|----------|-----------|
| | 0.25 c.c. | 0.05 c.c. | 0.1 c.c. | 0.2 c.c. | No serum. |
| Brilliant green 0.05 c.c. 0.1 per cent. solution | 0 | Marked | Complete | Complete | 0 |

Control : 0.5 c.c. ox's corpuscles + 0.5 c.c. heated rabbit serum = no lysis.

Lysis of 0.5 c.c. 5 per cent. Suspension Ox's Corpuscles treated with Brilliant Green (0.05 0.1 per cent. Solution per 0.5 c.c. Suspension) and washed free of Excess by Method detailed in Text.

| + Heated rabbit's serum (55° C.). | | | | |
|-----------------------------------|-----------|----------|----------|-----------|
| 0.025 c.c. | 0.05 c.c. | 0.1 c.c. | 0.2 c.c. | No serum. |
| Just complete | Complete | Complete | Complete | 0 |

TABLE VII.

Lysis of 0.5 c.c. 5 per cent. Suspension of Ox's Corpuscles treated with Brilliant Green (0.05-0.1 per cent. Solution per 0.5 c.c. Suspension and washed free of Excess).

| + Heated rabbit's serum (55° C.). | | | | |
|-----------------------------------|----------|------------|-----------|-----------|
| 0.005 c.c. | 0.1 c.c. | 0.025 c.c. | 0.05 c.c. | No serum. |
| Almost complete | Complete | Complete | Complete | 0 |

| + Varying amounts of brilliant green 0.1 per cent. solution (isotonic). | | | | |
|---|-----------------|----------|----------|----------|
| | 0.05 c.c. | 0.1 c.c. | 0.2 c.c. | 0.3 c.c. |
| 0.025 c.c. rabbit's serum (heated) | Almost complete | 0 | 0 | 0 |
| No serum | 0 | 0 | 0 | 0 |

Control: 0.5 c.c. ox's corpuscles + 0.5 c.c. heated rabbit's serum = no lysis. (Vide text for explanation.)

TABLE VIII.

Lysis of 0.5 c.c. 5 per cent. Suspension Ox's Corpuscles treated with Brilliant Green.

| | 0.025 c.c. | 0.05 c.c. | 0.1 c.c. | No serum. |
|--------------------------------|-----------------|-----------|----------|-----------|
| Fresh rabbit's serum | Almost complete | Complete | Complete | 0 |
| | 0.125 c.c. | 0.25 c.c. | 0.5 c.c. | |
| Boiled serum, 1 : 5 | Just complete | Complete | Complete | 0 |

Control: 0.5 c.c. ox's corpuscles + 0.5 c.c. rabbit's serum = no lysis.

TABLE IX.

Lysis of 0.5 c.c. 5 per cent. Suspension of Ox's Corpuscles treated with Brilliant Green.

| | 0.025 | 0.05 c.c. | 0.1 c.c. | No serum. |
|---------------------------|---------------|---------------|----------|-----------|
| Rabbit's serum . . . | Just complete | Complete | Complete | 0 |
| Albumin . . . | Distinct | Very marked | " | 0 |
| Globulin from "end piece" | 0 | Marked | " | 0 |
| "Mid piece" . . . | Marked | Just complete | " | 0 |
| Three fractions combined | Just complete | Complete | " | 0 |

Control: 0.5 c.c. ox's corpuscles + 0.5 c.c. rabbit's serum = no lysis.

TABLE X.

Lysis of 0.5 c.c. 5 per cent. Suspension Ox's Corpuscles treated with Brilliant Green.

| | 0.025 c.c. | 0.05 c.c. | 0.075 c.c. | 0.1 c.c. | 0.15 c.c. | No lecithin. |
|---|------------|-----------|------------|-------------|-----------|--------------|
| Lecithin 0.75 per cent. alcoholic solution 1 part in 8 parts of 0.85 per cent. NaCl | 0 | Trace | Marked | Very marked | Complete | 0 |
| Control: Alcohol 1 part in 8 parts 0.85 per cent. NaCl | 0 | 0 | 0 | 0 | 0 | 0 |

Control: 0.5 c.c. ox's corpuscles + 0.3 c.c. lecithin 1 : 8 = no lysis.

TABLE XI.

Lysis of 0.5 c.c. 5 per cent. Suspension Ox's Corpuscles treated with Brilliant Green.

| | 0.025 c.c. | 0.05 c.c. | 0.1 c.c. | No serum. |
|--|-----------------|-----------------|----------|-----------|
| Fresh rabbit's serum . | Almost complete | Complete | Complete | 0 |
| | 0.125 c.c. | 0.25 c.c. | 0.5 c.c. | |
| Serum 1.5 extracted with alcohol and ether | Marked | Almost complete | Complete | |

TABLE XII.
Lysis of 0.5 c.c. Suspension Ox's Corpuscles Treated with Brilliant Green.

| | 0.025 c.c. | 0.05 c.c. | 0.1 c.c. | 0.2 c.c. | No serum. | Lysis of 0.5 c.c. ox's corpuscles. |
|--------------------|-----------------|-----------------|----------|----------|-----------|------------------------------------|
| | | | | | | |
| Rabbit's serum (a) | Almost complete | Complete | Complete | Complete | — | 0 |
| Guinea-pig's serum | Complete | " | " | " | 0 | 0 |
| Ox's serum | " | " | " | " | 0 | 0 |
| Sheep's serum | Marked | Almost complete | " | " | 0 | 0 |
| Human serum (1) | Trace | Complete | 0 | 0 | 0 | 0 |
| " (2) | Marked | " | 0 | 0 | 0 | 0 |
| " (3) | Disfined | " | 0 | 0 | 0 | 0 |
| " (4) | Complete | 0 | 0 | 0 | 0 | 0 |

Lysis of 0.5 c.c. Suspension of Sheep's Corpuscles Treated with Brilliant Green.

| | 0.005 c.c. | 0.01 c.c. | 0.025 c.c. | 0.05 c.c. | No serum. | |
|--------------------|------------|-----------|------------|-----------|-----------|---|
| | | | | | | |
| Rabbit's serum (a) | 0 | Marked | Complete | Complete | 0 | 0 |
| Human serum (4) | Complete | Complete | 0 | 0 | 0 | 0 |

Lysis of 0.5 c.c. 5 per cent. Suspension of Guinea-pig's Corpuscles Treated with Brilliant Green.

| | 0.005 c.c. | 0.01 c.c. | 0.025 c.c. | 0.05 c.c. | No serum. | |
|-----------------|------------|-----------|------------|-----------|-----------|--|
| | | | | | | |
| Human serum (5) | Trace | Marked | Complete | Complete | 0 | |

TABLE XIII.
Lysis of 0.5 c.c. Suspension Ox's Corpuscles treated with Brilliant Green.

| Human. | 0.025 c.c. | 0.05 c.c. | 0.075 c.c. | 0.1 c.c. | 0.15 c.c. | 0.2 c.c. | No C.S.F. | 0.5 c.c. suspension of ox's corpuscles: no brilliant green. | |
|------------------------------|-------------|-----------------|---------------|-----------------|-----------------|----------|-----------|---|--|
| | | | | | | | | 0.2 c.c. | |
| Cerebro-spinal fluid (1) | 0 | Distinct | Marked | Very marked | Almost complete | Complete | 0 | 0 | |
| Cerebro-spinal fluid (2) | 0 | Trace | Distinct | Marked | Very marked | Complete | 0 | 0 | |
| Cerebro-spinal fluid 100° C. | 0 | Distinct | Marked | Very marked | Complete | Complete | 0 | 0 | |
| Cerebro-spinal fluid (3) | Marked | Almost complete | Complete | Complete | 0 | 0 | 0 | 0 | |
| Cerebro-spinal fluid (4) | Marked | Very marked | Very marked | Almost complete | Complete | 0 | 0 | 0 | |
| Cystic fluid | 0.065 Trace | 0.075 Marked | 0.01 Complete | 0.05 Complete | — | — | — | 0.5 = 0 | |

TABLE XIV.

Lysis of 0.5 c.c. 5 per cent. Suspension Ox's Corpuscles treated with Brilliant Green.

| | 0.025 c.c. | 0.075 c.c. | 0.1 c.c. | 0.2 c.c. | 0.3 c.c. | 0.5 c.c. | 0. |
|--|------------|------------|----------|----------|---------------|---------------|----|
| Albumin from urine suspended in 0.85 per cent. NaCl. (<i>Vide text</i>) | 0 | 0 | 0 | Trace | Dis- tinct | Com- plete | 0 |

Control: 0.5 c.c. ox's corpuscles + 0.7 c.c. suspension albumin from urine =
no lysis.

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ON THE VELOCITIES OF TWO DISTINCT GROUPS OF
SECONDARY CORPUSCULAR RAYS PRODUCED BY A
HOMOGENEOUS RÖNTGEN RADIATION, AND THEIR
ABSORPTION COEFFICIENTS IN VARIOUS GASES.

BY LEWIS SIMONS, B.Sc.(LOND.).

(With six Text-figures.)

(Figs. 2, 3 and 5 are in the form of folding plates and are inserted
together at the end of the paper.)

PART I.

The emission of a so-called homogeneous corpuscular radiation from a metal plate during the incidence of Röntgen rays upon it has been studied in detail by Sadler* and Beatty.† By using homogeneous beams of Lenard rays Whiddington showed that the law expressing their velocity as a function of the depth of matter passed through could be written‡—

$$(i) \quad \dots v_o^4 - v_x^4 = ax,$$

the constant a depending upon the nature of the absorbing material, but no relationship could be traced between the value of a and the density or atomic weight of the absorbers. In a later paper§ he showed, from the experimental results of Sadler and Beatty, that the maximum velocity of the corpuscular rays ejected by a characteristic Röntgen radiation was proportional to the atomic weight of the radiator supplying the Röntgen rays, and that this maximum velocity was independent of the nature of the substance from which they were ejected. Barkla and Shearer|| have extended this result so as to include either the "K" or "L" cathode rays, their conclusion being that the maximum velocity of ejection of the particles, wherever be their source in the atom, is the same for the incidence of a given wave-length of Röntgen radiation.

The object of the work undertaken in this paper was twofold:

(1) To investigate the absorption coefficients of the secondary corpuscular rays in various gases.

* 'Phil. Mag.' [6] xix, p. 337 (1910).

† *Ibid.*, [6] xx, p. 320 (1910).

‡ 'Proc. Roy. Soc.' A, lxxxvi, p. 370 (1912).

§ *Ibid.*, p. 376.

|| 'Phil. Mag.' [6] xxx, p. 753 (1915).

(2) To find, if possible, a velocity distribution, from the maximum downwards, of the particles about the radiator.

With regard to (1), a fairly complete summary of the work already done for the gases, air, and hydrogen is given in Kaye's 'X Rays,' 1917, whilst, in the case of (2), Richardson remarks. "The experiments hitherto made which bear on this point (that in general there will be other groups of electrons for which the maximum energy may in general have any value between $h\nu$ * and zero) have been directed to the determination of the maximum energy of the whole group of electrons, and would not be expected to detect the simultaneous presence of groups having a less degree of maximum energy than that value."†

The experimental results of this paper were obtained during the first three months of 1918.

If there exists a velocity distribution of the electrons, then it must be noted that the absorption coefficients of Sadler and Beatty are mean values. The following points are noted :

- (1) The electrons are emitted from the plate initially in every direction.
- (2) The maximum distance they can travel in air at normal pressure is a few millimetres, this being the length of the track of gaseous ions each produces by bombardment. These tracks are very irregular in shape.
- (3) The initial speed of ejection conforms approximately to Whiddington's law, $v_0 = kw$, where k is a constant and w the atomic weight (more probably twice the atomic number) of the radiator supplying the Röntgen rays.
- (4) The ionisation per cm. of the path of each electron is proportional to its fall of kinetic energy per cm. which is governed by equation (i).
- (5) The only method of arriving at an absorption coefficient in a gas, if absorption coefficient in this respect has any meaning, is by measuring, directly or indirectly, the number of secondary gaseous ions produced at different distances from the plate emitting the original electrons.

As early as 1895 Lenard showed that λ/d was practically constant for both gaseous and solid substances (λ is the logarithmic absorption coefficient and d the density of the absorber) for cathode particles emerging from a window of aluminium in a discharge tube. He showed that the absorption coefficient was logarithmic, and it measured the change in energy of the cathode particles in their passage through matter. Friman‡ has shown that when the error for diffusion has been allowed for, the absorption coefficient of the fast-moving β -rays from uranium-X in oxygen, carbon dioxide, and the vapour of acetone is approximately proportional to the

* $h\nu$ = the quantum of characteristic Röntgen radiation which falls on the plate emitting the electrons.

† 'Proc. Roy. Soc.' A, xciv, p. 272 (1918).

‡ 'Ann. der Physik,' xlix, 4, p. 373 (1916).

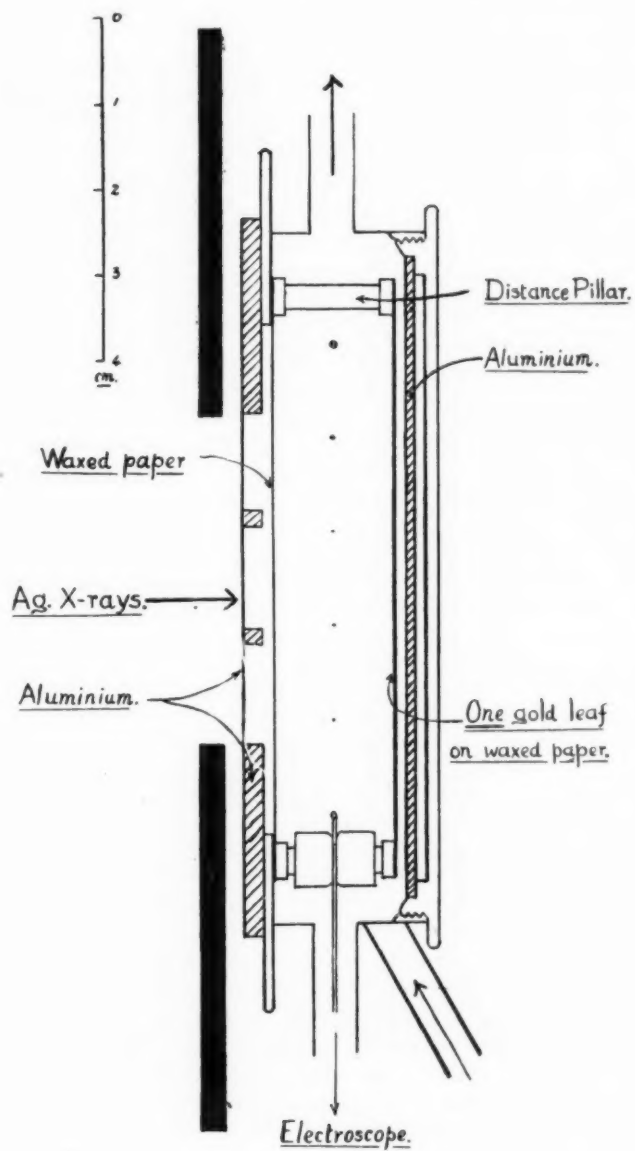


FIG. 1.

density of these substances. In more complex substances there is a marked deviation from proportionality.

The method employed in this work for the determination of the absorption coefficients of the corpuscular rays in various gases was the "pressure variation" method used by Beatty. The gases used were air, O_2 , CO_2 , SO_2 , which were passed slowly through a shallow ionisation chamber, a section of which is given in Fig. 1. The gas pressure could be varied from approximately zero up to atmospheric pressure, and the ionisation measured with an ordinary Wilson electroscope. The quantity of radiation falling into the chamber was standardised in the usual way with a standardising electroscope, and as silver X rays were used throughout, a screen of aluminium 0.75 cm. thick was placed in the path of the beam of X rays before it entered the chamber in order to eliminate the very easily absorbed L-radiation from the silver plate. Two complete sets of experiments were performed, giving the two sets of curves shown in Fig. 2. In the upper four, using the four gases successively at various pressures, the silver X rays fell on a sheet of gold leaf stuck on a sheet of waxed filter-paper which backed the chamber. In the lower four the conditions were precisely the same, except that the gold leaf was now absent. The ordinary "reflection" method was employed for obtaining a homogeneous beam.

The ionisation chamber possessed two unique features. The first was the electrode, which was a grid of about 2 cm. mesh of new, very fine carbon filament used in electric lamps. This was charged to a potential of about 240 volts. The second was the thinness of the gold screen. Any attempt to detect a true velocity distribution of the cathode particles characteristic either of the incident X rays or of the absorbing screen would require an infinitely thin screen so as to eliminate the effects of particles emerging from deeper layers in it. Hence it was that only one gold leaf was employed at the back of the chamber. Its thickness was calculated to be 0.000008 cm. Using formula (i) we have, according to Whiddington, a (for gold) = 2.54×10^{13} , $x = 0.000008$ cm., $v_0 = 108 \times 10^8$. On calculating v_x it is seen that the fall in speed of the fastest cathode particles, or of those having an initial velocity of, say, $\frac{1}{2}v_0$, will be inappreciable compared with their maximum initial velocities if they were generated at the back of the gold leaf and had to penetrate it in order to emerge into the ionisation chamber.

Preparation of the Gases.

Air.—Atmospheric air roughly dried by bubbling through strong H_2SO_4 .

Oxygen.—From the electrolysis of dilute H_2SO_4 . The ozone was removed by passing the gas through a glass tube immersed in a sand-bath kept at about $260^\circ C$. and then dried by passing through strong H_2SO_4 .

Carbon dioxide.—From commercial HCl and marble and dried with H_2SO_4 .

Sulphur dioxide.—From Johnson's "Pure Sodium Sulphite" and H_2SO_4 . Dried H_2SO_4 .

The gas flowed gently through the chamber and into a large vessel of about 10 litres capacity connected to its exit. This arrangement was to ensure that the gas in the chamber should be steadily replenished, but that the pressure within should not vary by more than a few millimetres of mercury during a run. The mean pressure was recorded.

The ordinates of the two curves for a given gas in Fig. 2 have been subtracted, giving the curves shown in Fig. 3. These curves represent the total ionisation produced in the gas at various pressures by the cathode particles from the gold leaf backing the chamber when silver X rays fall upon it.*

At this point it would not be out of place to indicate the manner in which the absorption coefficients have been obtained from the "cathode ionisation" curves in Fig. 3, as in the latter part of the paper the exact process has to be kept in mind.

Consider an instantaneous distribution of ions represented by Fig. 4 *b*. There is a critical pressure P at which, for a given initial speed of ejection, the ionising property of the least scattered cathode particle persists until the other side of the chamber is just reached. For this pressure let ρ_0 be the number of ions present per c.c. in a thin slab of gas next to the gold leaf. Next, assuming that the number of ions produced per c.c. from any cause be proportional to the density of the gas, then at a pressure $2P$ the density of ions at the gold radiator will be $2\rho_0$, but now the maximum distance traversed by the least scattered particles will be $l/2$. In other words, doubling the pressure halves the linear dimensions of the ionised track of each electron without altering the shape of the track, whatever that may be. The condition is represented by Fig. 4 *a*. Coming now to the case in which the pressure is $P/2$, the most normally directed electrons would ionise, were they not absorbed by the front face of the chamber, up to a maximum distance of $2l$ from the gold leaf, and the density of the ions at the gold leaf $= \rho_0/2$. The areas of all the curves are equal.

Reference to the cathode ionisation curves will show that condition (*b*) is represented by the point B on the air curve, (*a*) by A and (*c*) by C. In

* More strictly it is the ionisation by the cathode particles from the gold, less that by those emerging from a sheet of waxed paper, plus the ionisation in the gas by the tertiary X rays from gold and all the effects due to it. The lower set of curves in Fig. 2 shows that the ionisation in the gas due to the cathode particles emerging from a sheet of waxed paper can be neglected. If any did exist their properties would not differ greatly from those from gold. The ionisation effect due to any tertiary X rays from the gold leaf would be proportional to the pressure of the gas, and, as the curves in Fig. 3 show no variation in the ordinate beyond a certain critical pressure, this effect can also be neglected.

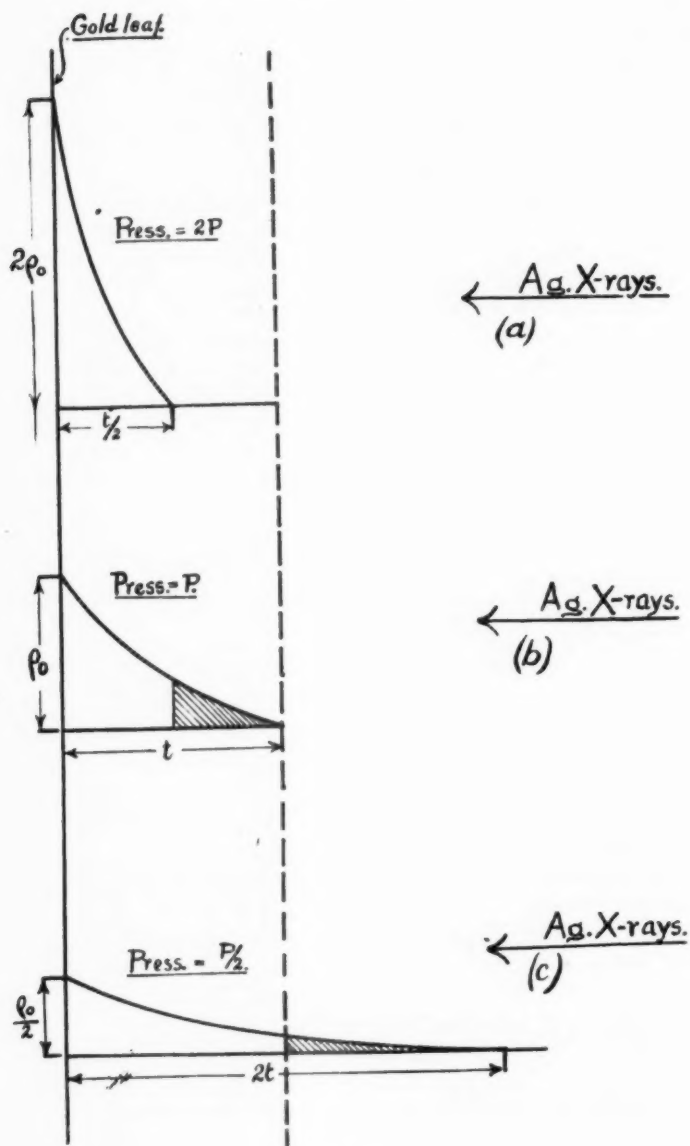


FIG. 4.

this last case the ions represented by the shaded toe are lost. This area equals that of the shaded toe of the curve Fig. 4, *b*.

It is to be remembered, however, that the ordinate on the cathode-ionisation curve at any given pressure p represents the area of the ionisation-density curve in Fig. 4 included between the two faces of the chamber. The ordinate CC' (Fig. 3) is a measure of the unshaded area in Fig. 4, *b*, and, therefore, if at the critical pressure the ionisation-density curve is given by—

$$\rho = \rho_0 f(x) \\ \text{then—} \\ CC' = \rho_0 \int_0^{1/2} f(x) dx = N_{t/2},$$

which equals the total number of ions existing at a given instant in a slab of half the thickness of the chamber, in this particular case.

It will be seen that $x = tp/P$ and that if the form of the function represented by the experimentally obtained cathode ionisation curve can be found, the first differential coefficient of this function gives the density distribution function of the ions across the chamber, with the possibility of determining the absorption coefficient.

First Approximation.

It will be seen from the figure that the cathode-ionisation curves proximate to $N_x = N_0(1 - e^{-\lambda x})$, and therefore the density ionisation in the chamber itself will be of the form $\rho = \rho_0 e^{-\lambda x}$, where $\rho_0 = N_0\lambda$ and λ is the absorption coefficient. If x be taken as the distance across the chamber at which the ionisation density becomes one-half of what it is at the gold screen, we obtain—

$$\lambda = \frac{\log_{10} 2}{x \times 4343} \quad \text{where } x = \frac{p}{P} \times 1.45 \text{ cm.},$$

since the depth of the chamber was 1.45 cm., P is the critical pressure for the gas in question, and p that pressure at which one-half of the ions that could be produced by the cathode particles are missing through the electrons having been absorbed by the opposite wall of the chamber. It will be noted that the absorption coefficient so found will be that at a pressure P , and therefore—

$$\lambda \text{ at N.T.P.} = \frac{\log_{10} 2}{p_{\frac{1}{2}} \times 1.45 \times 4343} \times 76 \times \frac{273 + T}{273}.$$

It will be noticed that P is absent.

The results obtained in this manner are tabulated in Table I. I have put them in this form for comparison with Beatty's results for air and hydrogen.

TABLE I. (Beatty's Method.)

Absorption Coefficients in Various Gases of the Corpuscular Rays produced by Characteristic Silver X rays. $w.l. = 560 \times 10^{-8}$ cm.

| Absorbing gas. | Total ionisation by complete absorption of corpuscular rays. | Values in column II relative to air = 1. | For comparison with column III. | μ obtained from curves, fig. 3. | Mean temp. | at 0° C. and 76 cm. | Density d . | λ/d . |
|-----------------|--|--|---------------------------------|-------------------------------------|------------|---------------------|---------------|---------------|
| H ₂ | — | — | 1, B. 102, B.P. | — | — | 80B* | 00009 | 8900 |
| Air | 748 | 1 | 1 | 4.12 cm. | 23° C | 9.56 | — | 7410 |
| O ₂ | 786 | 1.05 | 1.10, B.P. | 3.46 " | 26° | 9.3, B† | 00129 | 7210 |
| CO ₂ | 738 | .99 | 1.02, B.P. | 2.32 " | 23° | 11.50 | 00143 | 8040 |
| SO ₂ | 88 | 1.18 | .96, B.P. | 2.30 " | 22° | 16.97 | 00198 | 8570 |
| | | | | | | 17.06 | 00293 | 5820 |
| Mean = | | | | | | | | 7660 |

B = Beatty, *loc. cit.*

B.P. = Barkla and Philpot, 'Phil. Mag.' [6], June (1913).

The mean value of λ/d found by Lenard in two experiments on absorption in air, two in hydrogen and one in sulphur dioxide was 3774. This was for cathode rays having a speed given by a fall through 30,000 volts. By using the value for e/m and the relationship $V_k = 10^8 A$, where V_k is the above speed and A the atomic weight of the metal supplying the characteristic X rays which would produce this maximum speed, it was found that rhodium (at. wt. 103) is the approximate metal; it is known also that $\lambda A^{\frac{1}{2}} = \text{constant}$. In this way I estimate that Lenard's constant would have been of the order 3120 had he used cathode rays excited by silver X rays. It appears, therefore, that the absorption coefficients in Table I are abnormally high.

It cannot be stated with certainty that Lenard's rays were homogeneous. The same is true of the rays employed in these experiments, as will appear from Part II of this paper.

* Estimated from $\lambda = .51$ at 15° C. for corpuscular rays from silver produced by Sn. X rays, using the relationship λ (at. wt.)⁴ = constant.

† Calculated from Beatty's value 8.8 at 15° C. for Ag. X rays falling on silver. Beatty corrected his values to 15° C. and 76 cm. pressure. Subsequent writers quote his figures as at 0° C. and 76 cm. pressure. See 'Phil. Mag.' [6] xx, p. 323 (1910).

PART II.

It has been shown in Part I that the absorption coefficients of corpuscular rays in various gases, found by a method similar to that adopted by Beatty in 1910 for air and hydrogen, are probably too high. The reason becomes apparent from a critical examination of the cathode ionisation curves. It was stated that they proximated to the form $N_x = N_0 (1 - e^{-\lambda x})$, which gives a logarithmic fall in the ionisation-density curve from the gold leaf backing the ionisation chamber, forwards. In this way a logarithmic absorption coefficient was found.

Plotting the logarithms of $N_0 - N_x$ against x (or p) should result in a

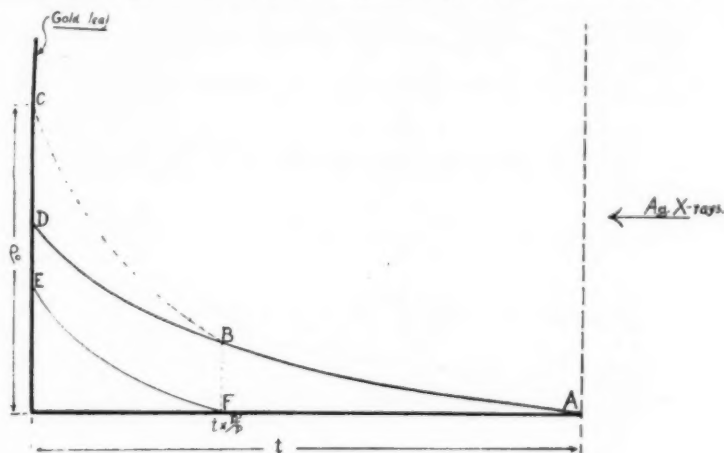


FIG. 6.

straight line. The cathode ionisation curves for the four gases were carefully drawn, and the logarithmic curves deduced from them are shown in Fig. 5. The departure of these curves from linearity is at once apparent; they are all concave upwards. On the air logarithmic curve, for example, a distinctly straight portion and a curved portion meet at B, and the curve shows no further tendency to "flatten out" beyond A. I therefore conclude that the slope of the line AB, which is perfectly straight, is a true measure of the absorption coefficient of the cathode particles and consequently a measure of their velocity. AB refers, however, to a faster group of particles, whilst CB refers to a slower group, as will be explained below. This latter group is completely absorbed in a distance $t \frac{P'_A}{P_A}$ at a pressure P_A , where this is the critical pressure for air for the faster group, P' , the pressure at B and t the depth of the ionisation chamber.

The corresponding ionisation-density curve is represented by the line CBA in Fig. 6, which is the summation curve of the two ionisation-density curves DBA and EF, corresponding to the ions produced by at least two distinct groups of corpuscles leaving the gold.

The method by which the logarithmic curve for the group of ions, whose ionisation-density curve is represented by EF (Fig. 6), was found, was to continue the line AB (Fig. 5) backwards, and to reconstruct from the antilogarithms the part of the curve BD (Fig. 6) which has its equivalent in OD in Fig. 3. The logarithm of the difference between this deduced cathode ionisation curve for the faster group and the experimentally obtained summation cathode ionisation curve for the two groups was again plotted against p (or x), giving the more sloping logarithmic curves in Fig. 5. Readings taken directly from these lines yield the following table of absorption coefficients:

TABLE II.
Showing that there are at least Two Distinct Groups of Particles ejected with Different Velocities from a Very Thin Gold Leaf when Silver X Rays fall upon it.

| Gas. | Density. | Temp. | P_1 | P_2 | λ | λ | λ/d | λ/d |
|-----------------|----------|--------|------------|------------|----------------------------------|-----------------------------------|-------------|-------------|
| | | | Fast rays. | Slow rays. | Fast rays at 0° C., 76 cm. | Slow rays at 10° C., 76 cm. | Fast rays. | Slow rays. |
| Air | 00129 | 23° C. | 7.36 cm. | 1.77 cm. | 5.35 | 22.25 | 4150 | 17250 |
| O ₂ | 00143 | 26° C. | 7.05 " | 1.53 " | 5.64 | 26.00 | 3950 | 18190 |
| CO ₂ | 00198 | 23° C. | 5.05 " | .90 " | 7.80 | 43.76 | 3940 | 22100 |
| SO ₂ | 00293 | 22° C. | 4.26 " | .91 " | 9.21 | 43.2 | 3150 | 14720 |
| Mean = | | | | | | | 3797 | 18065 |

Ratio = 4.76

The mean value of λ/d for the fast rays approaches closely Lenard's probable value that I have calculated at the end of Part I, viz. 3120. As lending support to the conclusion that there are two distinct groups of particles present, "the experiments of C. T. R. Wilson* on the photography of the tracks of the emitted electrons in gases indicate that for monochromatic radiations they would consist of a limited number of definite lengths rather than a series extending from zero to an upper limit."†

On these grounds, I think that the present accepted values of the absorption coefficients in air and hydrogen for the fastest corpuscular rays ejected from a plate by silver characteristic rays will need modification.

* Proc. Roy. Soc. A, vol. xxxvii.

† O. W. Richardson, Proc. Roy. Soc. A, vol. xciv, p. 271 (1918).

I should like further to point out that each member of the second group of logarithmic curves begins to rise again very near to where $p = 0$, indicating the presence of a third group of corpuscles whose speed is less than that of the second group. Further, if the shape of the logarithmic ionisation density curves can be associated with Kaye's* logarithmic absorption (or rather selective transmission) curves, and if from further experiment accurate numerical relationships can be deduced as below as to the relative energies of sets of corpuscles liberated from a metallic surface, then great light will be thrown upon the mechanism of absorption by solids generally.

I have shown elsewhere,† from a theory put forward by Barkla,‡ viz. that for each quantum of energy absorbed there is emitted, if the wave-length is short enough, one high-speed electron together with quanta of K, L, radiations, etc., that in the region of an L absorption band the sudden fall in the constant of proportion between the absorption of energy per atom ionised and the fourth power of the atomic number of the absorber

$$= \frac{\nu_L + \nu_M + \dots}{\nu_M + \dots} = 4.8$$

if the absorber have an atomic weight approximately that of gold. ν_L, ν_M , etc., are the frequencies of X-ray spectra corresponding to the L, M, etc., emission lines of the absorber. It was for this reason that silver was chosen as radiator and gold as screen for emitting particles, for as the K wave-length for silver is intermediate between the K and L wave-lengths for gold, then only the L, M, etc., characteristic groups of particles would be produced. If the energies of the particles bore a simple relationship to the energy absorbed in their production, then it was presumed that the ratio of their absorption coefficients would be neither too great nor too small to be detected by this method.

(The corresponding ratio for K and L corpuscles from gold would probably lie between 7 and 8.)

It is perhaps too soon to draw any definite conclusions as to the exact processes involved, but I shall show that the ratio shown in Table II is not in conflict with the general photo-electric equation.

The fundamental law of photo-electric activity is $\frac{1}{2}mv^2 = h\nu - w$, in which $\frac{1}{2}mv^2$ represents the maximum kinetic energy of the liberated electrons, h is Planck's constant, ν the frequency of the exciting radiations, and w a constant which measures the work necessary to be done to get an electron out of the sphere of influence of the parent atom. Independent experiments of Hughes§ and Millikan|| have shown that the equation is valid so far as

* 'Phil. Trans. Roy. Soc.,' A, ccix, p. 137 (1919); also 'X Rays,' p. 126 (1917).

† 'Trans. Roy. Soc. S. Af.,' vi, Pt. 4, p. 321 (1917).

‡ 'Nature,' March 4, 1915, p. 7.

§ 'Phil. Trans.,' A, vol. ccxii, p. 205 (1912).

|| 'Phys. Rev.,' vol. vii, pp. 18, 355 (1916).

experiments with ordinary light are concerned; but for X rays Richardson* says: "So far it has only been demonstrated as a limiting condition—that is to say, when matter is subjected to the action of radiation of frequency ν , no electron ever acquires a total energy, kinetic ($\frac{1}{2}mv^2$) and potential (w), in excess of $h\nu$." Very little is known about (w), which, according to Bohr, is the energy radiated away from the atom during the previous binding of the electron into it.

In the experiments hitherto made on the maximum speed of ejection of electrons by X rays it follows that they must have come from the periphery of the atom. The important conclusion drawn, that v depended only upon ν and in no way upon the nature of the substance emitting the electrons, does not satisfy the complete photo-electric equation.

Whatever be the source of the ejected electrons in the case of X rays, it is indisputable from the experimental evidence at hand that for the highest speed electrons w must be very small compared with the other two terms. The very small variation in Beatty's absorption coefficients for the particles in air with variation of the nature of the metal of the screen from which they emerge, if the incident wave-length is constant, indicates the approximate truth of the last statement.

If the equation $\frac{1}{2}mv^2 = h\nu$ (where w is neglected) apparently holds good for all screens, it should be reversible. Identifying the kinetic energy of a particle with the product of its charge and the potential through which it has fallen, the experiments of Rutherford, Richardson and Barnes† show that this abbreviated equation is by no means true, but that there is a limiting frequency obtainable from a given target. Likewise Duane and Hunt‡ show that $Ve = h\nu$ accurately, over a small range of wave-lengths, their value of h being smaller by about 2 per cent. than Millikan's accurate value 6.55×10^{-27} , pointing to the possibility that a small constant negative term might be missing from the right-hand side of their equation.

The potential energy term in the photo-electric equation seems to acquire reality in the case of the slower group of electrons described herein. Their velocity should be given by—

$$\frac{1}{2}mv_{\text{slow}}^2 = A_R h\nu_K - A_V(h\nu_L + h\nu_M + \text{etc.}).$$

Putting $m = 8.9 \times 10^{-28}$ gm., $h = 6.55 \times 10^{-27}$ erg. sec., $A_R\nu_K = 5.855 \times 10^{18}$ (mean frequency of α, β, γ lines after Bragg), $A_V\nu_L = 2.538 \times 10^{18}$, $A_V\nu_M = \nu_{L\beta} - \nu_{L\alpha} = 417 \times 10^{18}$ ($A_V\nu_{L\beta} = 2.748 \times 10^{18}$ and $A_V\nu_{L\alpha} = 2.331 \times 10^{18}$ and $A_V\nu_L$ is taken as the mean of these) we obtain for the velocity of the slower corpuscle a value 65×10^8 cm./sec. If the missing terms of the equation were known, the velocity would be slightly less than this amount.

Now Thomson has shown on theoretical grounds that for these particles

* *Loc. cit.*

† 'Phil. Mag.' [6] xxx, p. 352 (1915).

‡ 'Phys. Rev.' [2] vi, p. 169 (1915).

diffusing through a gas the absorption coefficient varies inversely as the fourth power of their velocity,* whilst Whiddington came to a similar conclusion from experimental work.† I have shown that—

$$\frac{\lambda_{\text{slow}}}{\lambda_{\text{fast}}} = 4.76 = \frac{v_{\text{fast}}^4}{v_{\text{slow}}^4},$$

and therefore the maximum velocity of the faster corpuscle = 96×10^8 cm./sec. This speed according to Whiddington = $10^8 A$, where A is the atomic weight of the metal supplying the X rays—silver in this case. He makes the speed therefore 108×10^8 cm./sec. This, however, is too high. He has shown that the maximum velocity of a particle is not greater than the minimum velocity of the parent cathode particle originally producing the X rays. By interpolation from the results of Rutherford, Barnes, and Richardson, the velocity of the parent cathode particle produced silver X rays of mean frequency 5.855×10^{18} is 98×10^8 cm./sec., by extrapolation from the results of Duane and Hunt 92×10^8 cm./sec., and from the simple equation $\frac{1}{2}mv^2 = h\nu - \lambda_c(h\nu)_K$, 93×10^8 .

Further work with thin films of other metals and with different radiators is in progress.

SUMMARY.

Part I.—The absorption coefficients in air, O_2 , CO_2 and SO_2 of the secondary corpuscular rays from gold associated with the L, M, etc., characteristic radiations produced by the incidence of silver X rays upon it have been found by the "pressure variation" method. The results agree approximately with Lenard's law and with Beatty's values ('Phil. Mag.,' [6] xx, p. 324, 1910) for air and H_2 . It is shown, however, that the absorption coefficients obtained by calculation from the pressure at which the cathode ionisation falls to half its maximum value are probably too high for the fastest corpuscles produced.

Part II.—To obtain as homogeneous a beam of particles as possible, a single very thin gold leaf was used as screen.

On carefully analysing the logarithmic cathode ionisation curves for the four gases, it was found that over a fair range each consists of a straight portion giving a logarithmic absorption coefficient for a faster group of particles, merging into a steeper curved portion rising to the axis $x = 0$, where x = distance from gold leaf, which was analysed with the help of the parent curve into a second straight portion giving a higher absorption coefficient than the first. The mean ratio of the two absorption coefficients is 4.76. It is suggested that at least two distinct groups of particles are present whose velocities from Thomson's fourth power law, as verified

* 'Cond. through Gases,' p. 381 (1906).

† 'Proc. Roy. Soc.,' A, lxxxvi, p. 375 (1912).

experimentally by Whiddington ('Proc. Roy. Soc.,' A, lxxxvi, p. 375, 1912), are in the ratio of 4.76^{-1} .

The maximum velocity of a corpuscle of the slower group, that associated with "L" characteristic radiation from gold, was calculated from the relationship—

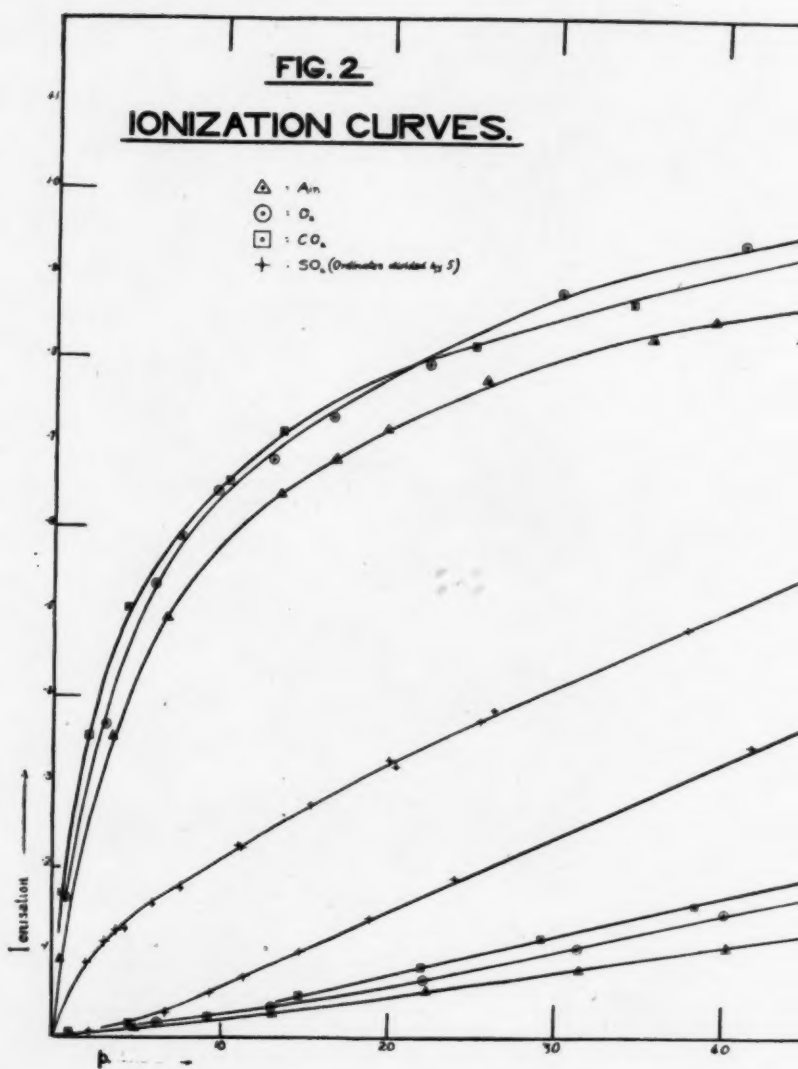
$$\frac{\frac{1}{2}mv^2}{\text{Energy of ex-}} = \frac{A_Z(h\nu)_K}{\text{pulsion. Quantum of incident}} - \frac{A_Z(h\nu_L + h\nu_M + \text{etc.})}{\text{energy. Potential energy of particle within the atom.}}$$

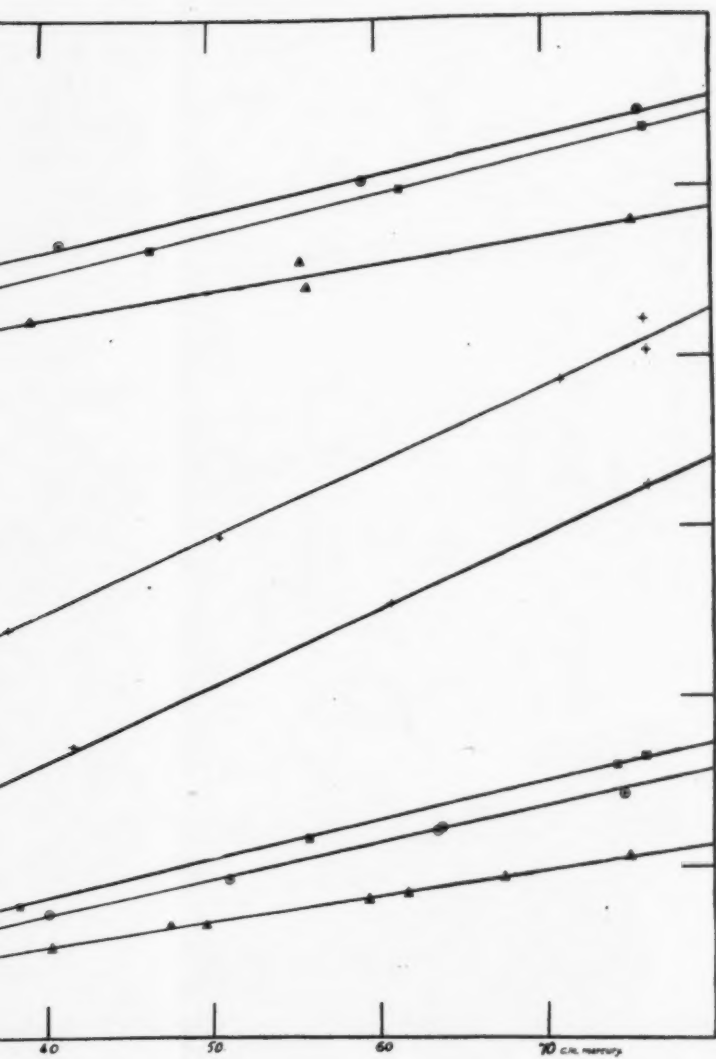
which gives a value 65×10^8 cm./sec., and therefore that of the faster corpuscle associated with "M" characteristic radiation from gold $= 96 \times 10^8$ cm./sec.

Whiddington's value for this is 108×10^8 cm./sec. (maximum velocity of a corpuscle ejected by silver X rays), whilst the mean of the values of the velocity of a parent cathode particle producing silver X rays (series K) calculated from the results of Rutherford, Barnes, and Richardson ('Phil. Mag.' [6], xxx, p. 352, 1915), from Duane and Hunt ('Phys. Rev.,' vi, p. 169, 1915), and from $\frac{1}{2}mc^2 = A_Z(h\nu)_K$ is 96.5×10^8 cm./sec. In writing down the above formula it is assumed that only one quantum of incident energy is absorbed, and that the nearer a particle be to the nucleus of an atom the greater will be the energy required to bring it to the surface before expulsion.

UNIVERSITY OF CAPE TOWN.

Read August 21st, 1918.





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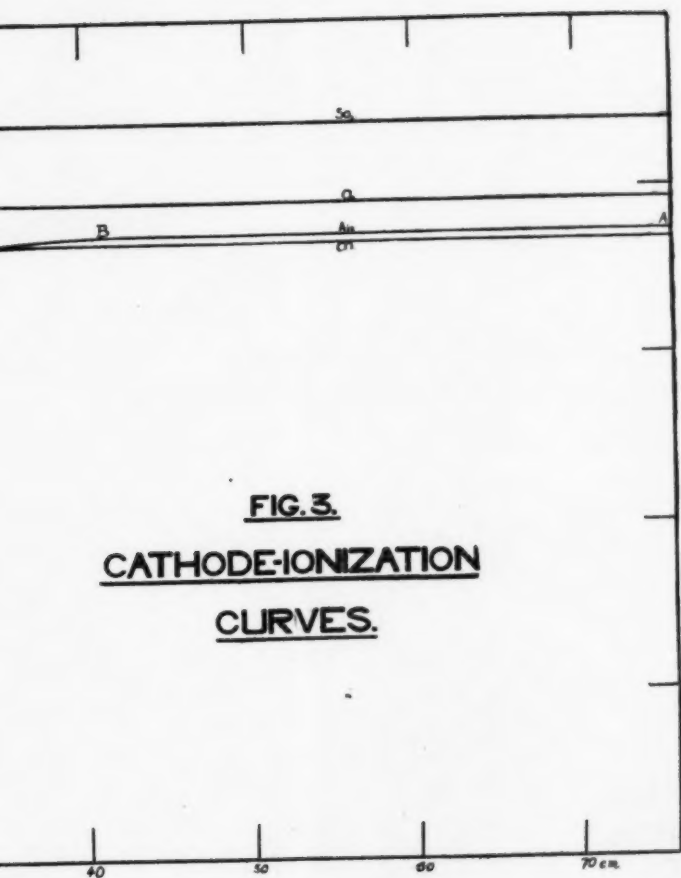
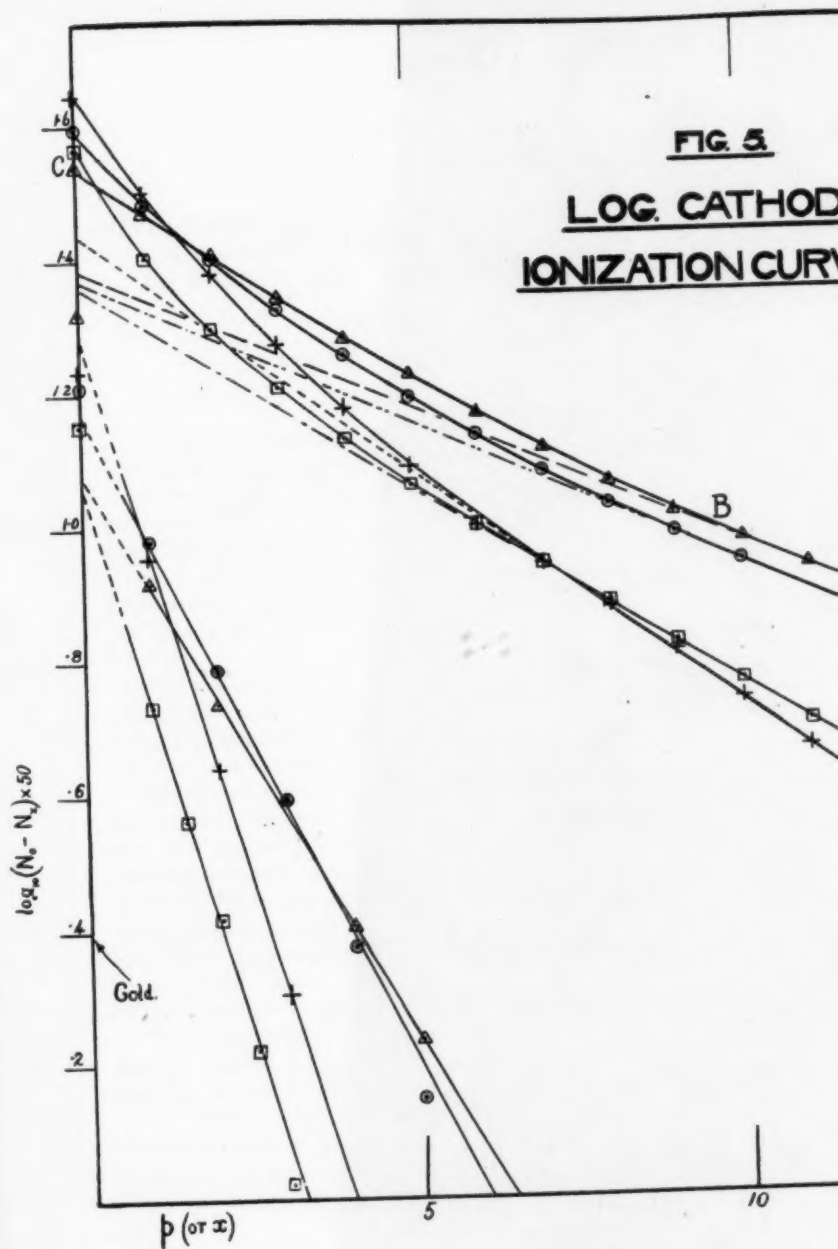
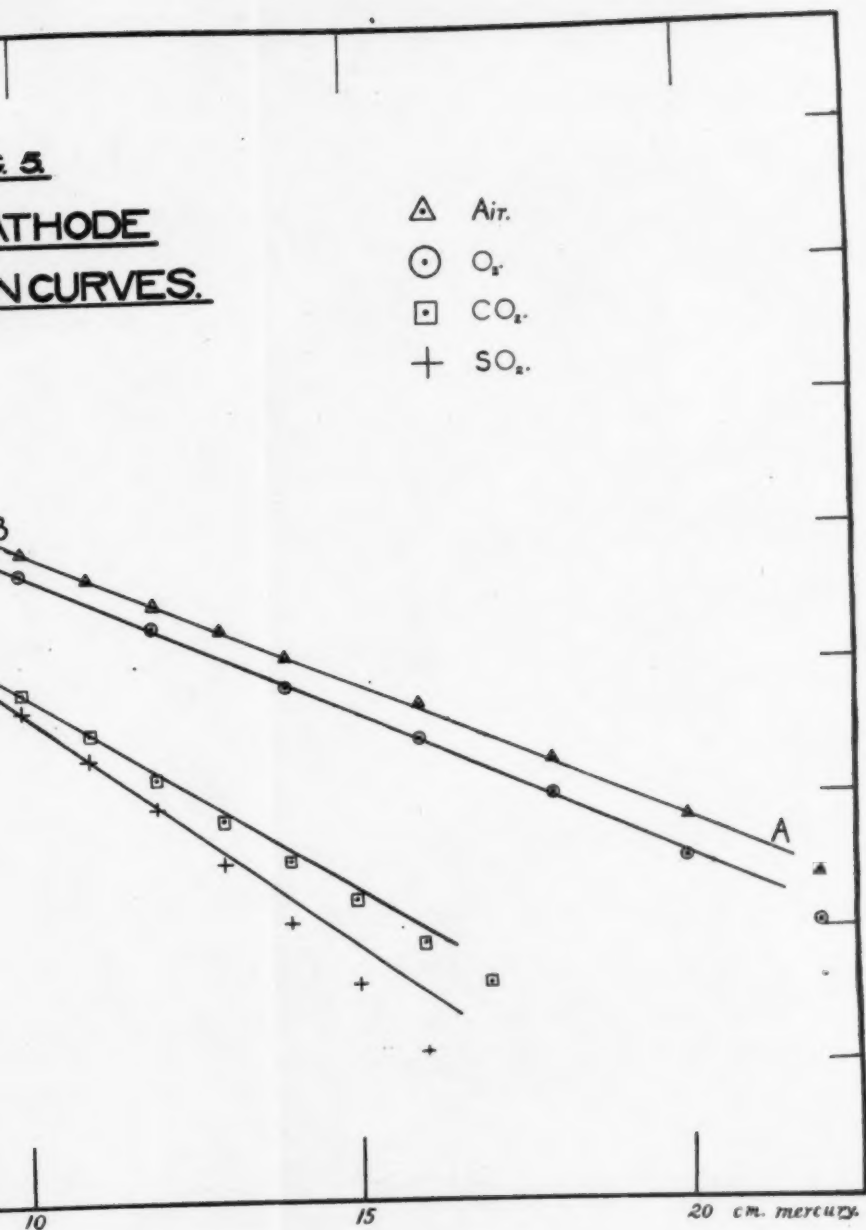


FIG. 3.
CATHODE-IONIZATION
CURVES.



5

CATHODE REDUCTION CURVES.



SOME NOTES ON A VISIT TO LAKE FUNDUSI IN THE
ZOUTPANSBERG DISTRICT OF THE TRANSVAAL, PAID
IN AUGUST, 1917.

By T. G. TREVOR, A.R.S.M., Inspector of Mines.

Communicated by DR. A. W. ROGERS.

(With Plate III.)

Though pans are common throughout South Africa, so far as the writer is aware Fundusi is the only sheet of natural water, south of the Zambesi, which can be described as a lake in the European sense, and as it lies in a most inaccessible position in a native territory and has been visited by very few white men, the following description may be of interest.

Some fifty miles south of the Limpopo a range of mountains called the Zoutpansberg runs parallel to the northern boundary of the Transvaal from the Magalagwin River almost to the Portuguese border—a distance of some 160 miles.

The western extremity of this range is known as Blaauwberg, and is separated from the main range by a wide gap, but from the eastern side of this gap at the Salt Pan the mountains are continuous for 100 miles till they die away near the Portuguese border.

The actual width of the mountain chain is never more than twenty miles. It is formed of Waterberg sandstones, lying often nearly horizontally, but generally with a dip towards the north of 10° – 20° . On both sides the mountains make an abrupt escarpment, rising to a general height of about 2000 ft. above the country at their foot. From an external view one would imagine the mountain top to be a wide plateau, and perhaps once it was, but at the present time it is deeply eroded into a series of longitudinal valleys of great depth, with very precipitous sides, and it is in one of these valleys that Lake Fundusi is situated.

To get to the lake it is necessary to ride or walk at least twenty miles from the nearest road, but as these miles are of the roughest description they may be said to make a good day's journey.

The writer, accompanied by Sir Robert Kotze, left the Native Commissioner's camp at Sibasa, on the southern foothills of the range, in the morning. The altitude of the camp is 2700 ft.; the path passes the Chief Sibasa's kraal just under the top of the mountain, about 1000 ft. above the

camp, and passing through a small belt of mist forest, emerges on an open down-like plateau, with scattered *Protea* trees and close-growing grass, which might be taken for a portion of the Transvaal high veld, though the actual altitude is under 4000 ft.

From here the path continues along the south edge of the mountain for some nine miles. At one point it passes an artificial circle of upright stones, with one larger dolmen on the east side, which immediately calls to mind the stone circles of Europe, and undoubtedly it has a similar origin, for our guide informed us that it was a sacred place of the Bavenda, who rest their dead there on their last journey to the Sacred Lake.

About three miles before reaching the lake the path begins to descend rapidly, and falls from an altitude of 4100 ft. at the summit to 3100 ft. at the high-water mark of the lake.

In the maps the lake is marked as a triangle. In fact, it fills a portion of a long valley and is probably 3000 yds. in length from the high-water mark at each end, with a subsidiary valley joining it on the south about two-thirds of the way up, the maximum breadth being about 500 yds. The river coming down the main valley is called the Motali, that coming in from the south the Fundusi.

All around the lake, the shores of which, except at the heads of the valleys, are either precipitous or else very steeply inclined, the vegetation stops abruptly at a well-defined high-water mark. About 40 ft. below this high-water mark there is in the southern valley a very pronounced terrace, which again was some 20 ft. above the water level at the time of our visit. As this terrace was covered with grass it is presumable that the water does not often rise above it.

From the junction of the southern valley to the lower end of the lake is an extremely rough scramble over scree and talus, just lying at its angle of rest, and slipping into the water on the slightest provocation.

When one comes in sight of the end of the lake the cause of its origin is obvious. The mountain to the north rises to a height of some 1800 ft. abruptly above a place where the original valley was narrowed by a ridge of rock, which projected into it from the south. In this mountain there is the scar of a huge landslide, which appears to have been about 300 yds. long and to have stretched about 100 yds. back into the top of the hill.

This mass has evidently slipped down and completely blocked the valley with a barrage of loose rock.

The scar is overgrown with vegetation, as is the barrage, and though the fall must have been recent, geologically speaking, it may be historically ancient.

On visiting the barrage it was found to be so rough that one could only climb about on it with great difficulty. Judging by the vegetation the water never overflows, but only gets to within some 20 ft. of the top, the

extra inflow of a rainy season being balanced by the extra leakage that each additional foot of water in the lake obtains through the barrage.

To the foot of the barrage, where the water comes out, is probably about 1200 yds. This is a most beautiful spot, as the water gushes out in dozens of "eyes" all surrounded by a natural grove of plantains.

The level of these "eyes" was, by aneroid observation, 2900 ft., or 170 ft. below the water level of the lake above.

The quantity of water escaping was not closely estimated, but it appeared to be about 10 cu. secs.

Along the shores of the lake the scenery is not particularly beautiful, and the footing is so rough as to be almost impracticable, but coming back from Maudoga, where the water emerges from the barrage, we found a high level path which was reasonably good walking and from which the view of the lake was lovely.

Apart from its interest as the only lake in the Union, Fundusi and the native tribe which inhabits the surrounding mountains should have a very great interest to ethnologists, for the Bavenda are entirely different to the ordinary Batu tribes of South Africa, and have different customs and language. To deal with these customs is out of the scope of this paper, nor is the author qualified to do so, but the following points about this tribe are noted here in the hopes that some interest may be aroused in them amongst ethnologists.

(1) The Bavenda at one time inhabited the Zimbabwe region and brought sacred stones from there to Zoutpansberg when they migrated.

(2) Amongst the Bavenda are certain "orthodox" families called "Malembi" who carry on many customs usually associated with the semitic races.

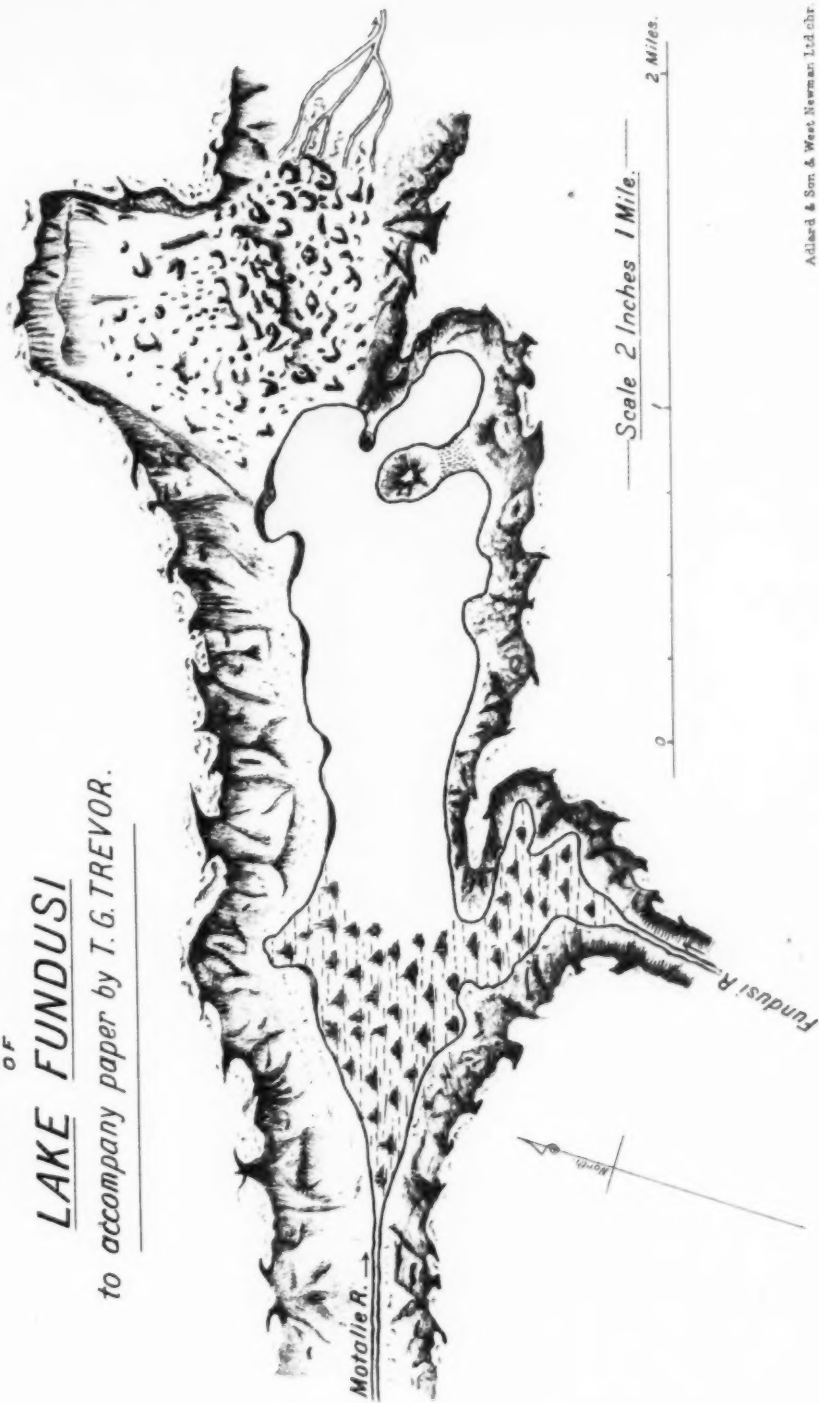
(3) The former Bavenda made quite considerable irrigation works, some of which are still in existence.

(4) Some of the Bavenda tribes still burn their dead, others throw their dead into sacred waters.

(5) Sacred stones and stone circles such as the one described on the path from Sibasa's to Fundusi are respected, if not erected by the tribe.

From the point of view of beauty Fundusi does not compare favourably with the majority of mountain lakes of Europe, but on the other hand the wildness of the surroundings, the peculiar nature of its origin, and the interest attaching to the tribe inhabiting the district, make it well worth a visit. In time to come, if the Motatie valley is inhabited by white men, the lake will become of immense practical value for irrigation purposes, as the barrage stores the surplus run-off of the rainy season and regulates the out-flow in a manner that could hardly be surpassed by an artificial dam with regulated sluice-gates.

SKETCH MAP
OF
LAKE FUNDUSI
to accompany paper by T. G. TREVOR.



NOTE ON THE SO-CALLED SECOND BRANCHIAL ARCH IN LIZARDS.

By JOHN HEWITT.

(With one Text-figure.)

The occurrence of an isolated cartilaginous element, apparently a branchial arch, in the neck of certain adult lizards was emphasised by Mr. F. E. Beddard in a paper "On the Anatomy of Certain Species of *Squamata*" ('Proc. Zool. Soc.,' 1907, p. 53). This element had been previously observed by Prof. W. K. Parker in the adult skull of *Lacerta agilis*, but, perhaps owing to a somewhat ambiguous description ('Phil. Trans.,' 1879, p. 616), the fact has been generally overlooked by the writers of text-books on vertebrate Zoology; there is, however, a clear account of the hyoid and branchial apparatus in T. J. Parker's chapter on the Lizard in his 'Zootomy,' p. 146.

It is commonly stated that, whereas the hyoid apparatus both of *Chelonia* and of *Lacertilia* is provided with two pairs of large horns, those of *Chelonia* belong to the first and second branchial arches, the hyoid arch being represented only by a small or obsolete horn, whilst in *Lacertilia* the two horns belong to the Hyoid and first branchial arches. As a matter of fact, the hyoidean apparatus of lizards (see Hoffmann in Bronn's 'Tierreich,' "Reptilien," p. 608, Taf. 72; Beddard in 'P. Z. S.,' 1905, p. 20; Shufeldt in 'P. Z. S.,' 1890, p. 224, Pl. 18) varies considerably, the two horns showing various degrees of development, whilst there may or may not be present a posterior bifurcation of the median piece which very probably is a persistent remnant of the second branchial arch, as thus considered by T. J. Parker. When present, this pair of basibranchial processes may be closely approximated in the middle line, or they may be widely separated as in *Pachydactylus bibroni* and some other geckoes; in closely allied genera they may be strongly developed or completely absent. The one character, which may point to the lack of true serial homology between these basibranchial processes and the two pairs of cornua, is the absence of any joint to mark them off from the median copula, whereas the cornua appear to be almost always articulated therewith. However, the presence of joints in the hyoidean apparatus seems to be sometimes merely a matter of function. At the anterior bend of the hyoid arch of lizards, the element is more or less completely divided into two, a dorsal and a ventral half, being completely so in *Varanus*, whilst, on the other hand, in *Gerrhosaurus validus* I have found no trace of a joint or separation into two halves. Again, in the Agamidae, as known to me in the genus *Agama*, the base of the hyoid arch has almost entirely fused up with the

copula; so much so that on examining the hyoid apparatus in ventral view the hyoid and copula seem to be completely continuous, although on careful examination of these parts from the dorsal side a joint is clearly indicated.

According to the figure given by Mr. Beddard for the Agamid genus *Chlamydosaurus* ('P. Z. S.' 1905, p. 20), the ventral portion of the hyoid presents the appearance of a lateral outgrowth from the copula, no demarcation between the two elements being represented, but *Goniocephalus*, another genus of the same family, as figured by Hoffmann in Bronn's 'Tierreich,' has a very distinct articulation marking the base of the hyoid arch.

Whatever may be the significance of the basibranchial processes in lizards, there can be no doubt but that the isolated cartilaginous elements noticed by Mr. Beddard in *Zonurus giganteus* (Zonuridae), in *Tiliqua* and *Trachydosaurus* (Scincidae), and in *Gerrhonotus* (Anguidae), represent portions of a branchial arch. According to T. J. Parker, they probably represent the epibranchial region of the second branchial arch, and Beddard also refers them to the same arch. In any case, they cannot be precisely homologous with the bar designated as the second branchial in the *Chelonia*—an element which, as previously stated, may really be the same as the basibranchial process of lizards. Their dorsal situation and the absence of any trace of connection between these elements and the copula apparently indicate an origin from the dorsal portion of a branchial arch, whereas the cornua and the basibranchial processes are no doubt derived from the ventral portions of the original arches. Further, it seems to me undesirable to refer this element to any particular arch at present, as the data available from dissection of an adult are insufficient for the purpose. They have no cartilaginous connection with any part of the hyoid apparatus, and it seems possible that they may be referable to any one of the arches therein represented, or to a succeeding arch. I shall therefore refer to them merely as the Epibranchials.

The results of the examination of a number of S. African lizards in search of the Epibranchials can be briefly recorded as follows:

Agamidae.—The epibranchials are absent. The whole hyoid apparatus in *Agama atricollis* is somewhat reduced, both cornua being rather short, and the hyoid being quite separated from the tympanic region.

Varanidae.—In *Varanus* the epibranchials are absent; the hyoid has no relation with the ear; the first branchial is greatly elongated.

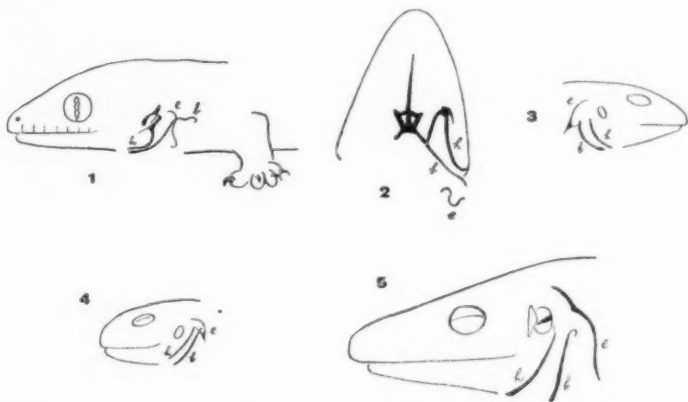
Chamaeleonidae.—The epibranchials are absent in *Chamaeleon quilensis*. The anterior and posterior cornua are considerably reduced.

Gerrhosauridae.—In *Gerrhosaurus validus* the epibranchials are present, being sometimes very distinct and ossified. They lie more deeply than the cornua, being separated therefrom by a band of muscles. The hyoid terminates at a considerable distance from the ear, but a very slender strand of ligament passes from its end to the tympanic region. *G. flavigularis* offers similar characters.

Scincidae.—*Mabuia trivittata* has distinct epibranchials. At the lower end of each bar is a short, forwardly-projecting process. According to Beddard, in the genus *Tiliqua* a ligament passes from this projecting process and is attached to the end of the hyoid cornu. The hyoid is separated from the ear.

Lacertidae.—In *Nucras delalandi* the whole hyoid apparatus is very much like that of *M. trivittata*. The ligamental strand between the lower portion of the epibranchial and the distal end of the hyoid is distinct.

Zonuridae.—In *Zonurus giganteus*, *Z. cordylus* and *Pseudocordylus microlepidotus* the epibranchials are present. The hyoid has no relation with the ear.



Hyobranchial apparatus of lizards. 1. *Homopholis wahlbergi* (fam. Geckonidae). 2. Same in ventral view. 3. *Mabuia trivittata* (fam. Scincidae). 4. *Nucras delalandi* (fam. Lacertidae). 5. *Gerrhosaurus validus* (fam. Gerrhosauridae). h. Hyoid arch. b. First branchial arch. e. Epibranchial.

Geckonidae.—In *Homopholis wahlbergi* and *Pachydaetylus bibroni* the epibranchial is present as a very slender thread of cartilage. The hyoid is intimately connected with the ear, passing along the posterior side of the tympanic membrane, which alone separates it from the columella. The hyoid and columella terminate very close together on the surface of the skull.

Although as yet comparatively few genera have been examined, it seems very likely that the epibranchials are normally present in the following families of lizards: Geckonidae, Lacertidae, Zonuridae, Scincidae, Gerrhosauridae and Anguidae; and are absent from Agamidae, Varanidae, Helodermatidae and Iguanidae. Its homology can only be worked out embryologically. In the meantime, the ligamental connection between the lower portion of the epibranchial and the upper end of the hyoid cornu in certain families can be noted but not explained.

NOTE ON UNIMODULAR AND OTHER PERSYMMETRIC
DETERMINANTS.

BY SIR THOMAS MUIR, LL.D.

(1) On pp. 201-204 of vol. xxxiv of the 'Edinburgh Mathematical Society's Proceedings' there is given, in regard to persymmetric determinants, an interesting set of three theorems, which on more than one account are deserving of comment. In the first place, unfortunately they are all inaccurately stated in a matter of sign, and the second of them is presented in a form that obscures its real character.

(2) For conviction on this latter point we have only to recall the fact that the determinant concerned, namely,

$$\begin{vmatrix} a_1 & a_2 & a_3 & a_4 & a_5 & a_6 \\ -a_1 & a_1 & a_2 & a_3 & a_4 & a_5 \\ -a_2 & -a_1 & a_1 & a_2 & a_3 & a_4 \\ -a_3 & -a_2 & -a_1 & a_1 & a_2 & a_3 \\ -a_4 & -a_3 & -a_2 & -a_1 & a_1 & a_2 \\ -a_5 & -a_4 & -a_3 & -a_2 & -a_1 & a_1 \end{vmatrix}$$

is, like all other even-ordered determinants, unaltered in substance by changing the signs of the main diagonal and every alternate parallel diagonal, this change giving

$$\begin{vmatrix} -a_1 & a_2 & -a_3 & a_4 & -a_5 & a_6 \\ -a_1 & -a_1 & a_2 & -a_3 & a_4 & -a_5 \\ a_2 & -a_1 & -a_1 & a_2 & -a_3 & a_4 \\ -a_3 & a_2 & -a_1 & -a_1 & a_2 & -a_3 \\ a_4 & -a_3 & a_2 & -a_1 & -a_1 & a_2 \\ -a_5 & a_4 & -a_3 & a_2 & -a_1 & -a_1 \end{vmatrix}$$

and showing that the negative signs belong simply to the variables a_1, a_3, a_5 , and do not contribute in any way to the specialisation of the determinant. Putting $+a_1, +a_3, +a_5$ for $-a_1, -a_3, -a_5$, and writing the determinant in the way adopted for persymmetries—that is to say, with its columns in the reverse order—we obtain the equality.

* Datta, H., "On Symmetrical Determinants and Pfaffians," 'Proc. Edin. Math. Soc.,' xxxiv, pp. 197-204.

$$= \begin{vmatrix} a_2 - a_1 & a_2 - a_3 & a_4 - a_3 & a_4 - a_5 & a_6 - a_5 \\ a_2 - a_1 & a_2 - a_3 & a_4 - a_3 & a_4 - a_5 & \\ a_2 - a_1 & a_2 - a_3 & a_4 - a_3 & \\ a_2 - a_1 & a_2 - a_3 & \\ a_2 - a_1 & \end{vmatrix} \cdot \begin{vmatrix} a_2 - a_1 & a_2 - a_3 & a_4 - a_3 & a_4 - a_5 & -a_5 \\ a_2 - a_1 & a_2 - a_3 & a_4 - a_3 & a_4 & \\ a_2 - a_1 & a_2 - a_3 & -a_3 & \\ a_2 - a_1 & a_2 - a_3 & -a_3 & \\ a_2 - a_1 & a_2 & -a_1 \end{vmatrix}$$

which, on utilising the property regarding change of sign in the alternate diagonals of a pfaffian, takes the final form

$$= \begin{vmatrix} a_2 - a_1 & a_3 - a_2 & a_4 - a_3 & a_5 - a_4 & a_6 - a_5 \\ a_2 - a_1 & a_3 - a_2 & a_4 - a_3 & a_5 - a_4 & \\ a_2 - a_1 & a_3 - a_2 & a_4 - a_3 & \\ a_2 - a_1 & a_3 - a_2 & \\ a_2 - a_1 & \end{vmatrix} \cdot \begin{vmatrix} a_2 - a_1 & a_3 - a_2 & a_4 - a_3 & a_5 - a_4 & a_5 \\ a_2 - a_1 & a_3 - a_2 & a_4 - a_3 & a_4 & \\ a_2 - a_1 & a_3 - a_2 & a_4 & a_3 & \\ a_2 - a_1 & a_3 - a_2 & a_3 & a_2 & \\ a_2 - a_1 & a_3 & a_2 & a_1 \end{vmatrix}$$

(3) Equating the co-factor of a_6 on the one side of this to the co-factor on the other side we obtain

$$= \begin{vmatrix} a_4 & a_3 & a_2 & a_1 & a_1 \\ a_3 & a_2 & a_1 & a_1 & a_2 \\ a_2 & a_1 & a_1 & a_2 & a_3 \\ a_1 & a_1 & a_2 & a_3 & a_4 \\ a_1 & a_2 & a_3 & a_4 & a_5 \end{vmatrix} \text{ i. e. } P(a_5, a_1, a_3, a_2, a_1, a_1, a_2, a_3, a_4) \\ = \begin{vmatrix} a_2 - a_1 & a_3 - a_2 & a_4 - a_3 & a_5 - a_4 & a_5 \\ a_2 - a_1 & a_3 - a_2 & a_4 - a_3 & a_4 & \\ a_2 - a_1 & a_3 - a_2 & a_4 & a_3 & \\ a_2 - a_1 & a_3 - a_2 & a_3 & a_2 & \\ a_2 - a_1 & a_3 & a_2 & a_1 \end{vmatrix}$$

which is the analogous theorem in the case of an odd-ordered determinant.

(4) In the second pfaffian which appears in both of the preceding results the last frame-line may be altered with impunity from

$$\begin{pmatrix} a_5 \\ a_4 \\ a_3 \\ a_2 \\ a_1 \end{pmatrix} \text{ to } \begin{pmatrix} a_4 \\ a_3 \\ a_2 \\ a_1 \\ a_1 \end{pmatrix}$$

for the reason that the fifth frame-line is the difference of the two. The latter form has the advantage of readily enabling us to equate the co-factors of a_5 in §2, and so arrive at the next lower case of the theorem, namely,

$$= \begin{vmatrix} a_2 & -a_1 & a_3 & -a_2 & a_4 & -a_3 \\ a_2 & -a_1 & a_3 & -a_2 & \\ a_2 & -a_1 & \\ a_2 & -a_1 & \\ a_2 & -a_1 & \end{vmatrix} \cdot \begin{vmatrix} a_2 & -a_1 & a_3 & -a_2 & -a_3 \\ a_2 & -a_1 & -a_2 & \\ a_2 & -a_1 & -a_2 & \\ a_2 & -a_1 & -a_2 & \\ a_2 & -a_1 & -a_2 & \end{vmatrix}$$

(5) The result in §3 is identical with the last of the three above mentioned when the latter has been corrected as to sign. Strictly speaking, therefore, Mr. Datta's contributions are *two* in number, namely, one regarding

$$P(a_n, a_{n-1}, \dots, a_1, a_2, \dots, a_{n-1}, a_n)$$

printed on p. 201 of his paper with minus instead of plus signs in the last frame-line of the second pfaffian; and the other regarding

$$P(a_n, a_{n-1}, \dots, a_1, a_1, a_2, \dots, a_{n-1})$$

as established above.

(6) In the case of the second mode of resolution, namely, into *determinants*, the factors are accurately given, serving indeed as a check on the pfaffian forms. I would only note in this connection that a companion to Zehfuss' theorem regarding the resolution of centrosymmetric determinants applies directly to $P(a_n, a_{n-1}, \dots, a_1, a_1, a_2, \dots, a_{n-1})$, namely, the theorem that any n -line determinant having the array of its last $n-1$ rows centrosymmetric is expressible as the product of two determinants; for example, when the order is even—

$$= \begin{vmatrix} u & v & w & x & y & z \\ a_1 & a_2 & a_3 & a_4 & a_5 & a_6 \\ b_1 & b_2 & b_3 & b_4 & b_5 & b_6 \\ c_1 & c_2 & c_3 & c_3 & c_2 & c_1 \\ b_6 & b_5 & b_4 & b_3 & b_2 & b_1 \\ a_6 & a_5 & a_4 & a_3 & a_2 & a_1 \end{vmatrix} \cdot \begin{vmatrix} u-z & v-y & w-x \\ b_6-b_1 & b_5-b_2 & b_4-b_3 \\ a_6-a_1 & a_5-a_2 & a_4-a_3 \end{vmatrix},$$

and when the order is odd—

$$= \begin{vmatrix} u & v & w & x & y \\ a_1 & a_2 & a_3 & a_4 & a_5 \\ b_1 & b_2 & b_3 & b_4 & b_5 \\ b_5 & b_4 & b_3 & b_2 & b_1 \\ a_5 & a_4 & a_3 & a_2 & a_1 \end{vmatrix} \cdot \begin{vmatrix} w & v+x & u+y \\ a_3 & a_4+a_2 & a_5+a_1 \\ b_3 & b_4+b_2 & b_5+b_1 \end{vmatrix}.$$

(7) Unconnected with the foregoing save in that the subject is still persymmetric determinants are the three following results:

$$P(1_0, 3_1, 5_2, 7_3, \dots) = 1,$$

$$P\left(\frac{1_0}{1}, \frac{3_1}{3}, \frac{5_2}{5}, \frac{7_3}{7}, \dots\right) = 1,$$

$$P(1_0, 1_1, 2_1, 3_2, 4_2, 5_3, 6_3, \dots) = 1,$$

where r_s stands for $r!/s! (r-s)!$ The first two determinants are seen to

have the peculiarity that the combinatory numbers involved in them are all of the type

$$(2r+1)_r:$$

they thus have a link of connection with the recurrences studied in a previous paper.*

(8) In seeking to verify any one of the three for a determinant of definite order the fact that the $(1, 1)^{\text{th}}$ element is 1 naturally suggests condensation into a determinant of the next lower order; for example,

$$\begin{vmatrix} 1 & 3 & 10 & 35 & 126 \\ 3 & 10 & 35 & 126 & 462 \\ 10 & 35 & 126 & 462 & 1716 \\ 35 & 126 & 462 & 1716 & 6435 \\ 120 & 462 & 1716 & 6435 & 24310 \end{vmatrix} = \begin{vmatrix} 1 & 5 & 21 & 84 \\ 5 & 26 & 112 & 456 \\ 21 & 112 & 491 & 2025 \\ 84 & 456 & 2025 & 8434 \end{vmatrix}$$

$$= \begin{vmatrix} 1 & 7 & 36 \\ 7 & 50 & 261 \\ 36 & 261 & 1378 \end{vmatrix} = \begin{vmatrix} 1 & 9 \\ 9 & 82 \end{vmatrix} = 1,$$

where, be it noted, the one process suffices to show that the determinants of orders 5, 4, 3 are equal to

$$\begin{vmatrix} 1 & 9 \\ 9 & 82 \end{vmatrix}, \begin{vmatrix} 1 & 7 \\ 7 & 50 \end{vmatrix}, \begin{vmatrix} 1 & 5 \\ 5 & 26 \end{vmatrix}$$

respectively, and consequently are all equal to 1.

(9) The most instructive general proof consists in multiplication by unity in the form—

$$\begin{vmatrix} 1 & . & . & . & . & . \\ -3 & 1 & . & . & . & . \\ 5 & -5 & 1 & . & . & . \\ -7 & 14 & -7 & 1 & . & . \\ 9 & -30 & 27 & -9 & 1 & . \\ . & . & . & . & . & . \end{vmatrix}$$

the k^{th} row of the multiplier being—

$$(-1)^{k-1}(2k-1)\left\{1, -\frac{1}{3}(k)_2, \frac{1}{5}(k+1)_3, \dots, (-1)^{k-1}\frac{1}{2k-1}(2k-2)_{2k-2}\right\}.$$

This leads to the product—

$$\begin{vmatrix} 1 & . & . & . & . & . \\ 3_1 & 1 & . & . & . & . \\ 5_2 & 5_1 & 1 & . & . & . \\ 7_3 & 7_2 & 7_1 & 1 & . & . \\ 9_4 & 9_3 & 9_2 & 9_1 & 1 & . \\ . & . & . & . & . & . \end{vmatrix}$$

* 'Trans. R. Soc. S. Africa,' viii, pp. 27-32.

which also being unity entails a unit multiplicand. The property of combinatory numbers which underlies the multiplication is—

$$(2h-1)_{h-1} = \frac{1}{3}(2h+1)_h k_2 + \frac{1}{5}(2h+3)_{h+1} (k+1)_4 \\ - \frac{1}{7}(2h+5)_{h+2} (k+2)_6 + \dots = (-1)^{k-1} \frac{1}{2h-1} (2h-1)_{h-k}.$$

(10) The second result,

$$P \left(\begin{matrix} 1_0 & 3_1 & 5_2 & 7_3 & \dots \\ 1 & 3 & 5 & 7 & \dots \end{matrix} \right) = 1,$$

can be established in similar fashion, the multiplier now being—

$$\begin{vmatrix} 1 & . & . & . & . & \dots \\ -1 & 1 & . & . & . & \dots \\ 1 & -3 & 1 & . & . & \dots \\ -1 & 6 & -5 & 1 & . & \dots \\ 1 & -10 & 15 & -7 & 1 & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \end{vmatrix}$$

of which the k^{th} row is—

$$(-1)^{k-1} \{ 1, -(k)_2, (k+1)_4, (k+2)_6, \dots, (-1)^{k-1} (2k-2)_{2k-2} \},$$

and the property of combinatory numbers underlying the multiplication being—

$$\frac{1}{2h-1} (2h-1)_h = \frac{1}{2h+1} (2h+1)_h k_2 + \frac{1}{2h+3} (2h+3)_{h+2} (k+1)_4 + \dots \\ = (-1)^{k-1} \frac{2h-1}{2h-1} (2h-1)_{h-k}.$$

Viewed in connection with the first result the second may be put thus :
If every element $(2r-1)_r$ of the first persymmetric be divided by $(2r-1)$ the determinant is unchanged in value.

(11) The third result, notwithstanding the peculiar law of formation of its determinant, can also be established in the same way, the multiplier and product being respectively

$$\begin{vmatrix} 1 & . & . & . & . & \dots \\ -1 & 1 & . & . & . & \dots \\ -1 & -1 & 1 & . & . & \dots \\ 1 & -2 & -1 & 1 & . & \dots \\ 1 & 2 & -3 & -1 & 1 & \dots \\ -1 & 3 & 3 & -4 & -1 & 1 & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \end{vmatrix} \begin{vmatrix} 1 & . & . & . & . & \dots \\ 1 & 1 & . & . & . & \dots \\ 2 & 1 & 1 & . & . & \dots \\ 3 & 3 & 1 & 1 & . & \dots \\ 6 & 4 & 4 & 1 & 1 & \dots \\ 10 & 10 & 5 & 5 & 1 & 1 & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \end{vmatrix}$$

with laws of formation as curious as that of the multiplicand. The k^{th} row of the former is best thought of as written from right to left, thus :

$$\dots \dots \dots -(k-4)_{k-6}, (k-3)_{k-5}, (k-3)_{k-4}, \\ -(k-2)_{k-3}, -(k-2)_{k-2}, (k-1)_{k-1},$$

where it will be seen that the only steady sequence occurs in the subscripts 0, 1, 2, . . . , $k-1$, the row of non-subscripts having $k-2$ duplicated and preceded by $-$, $k-3$ duplicated and preceded by $+$, $k-4$ duplicated and preceded by $-$, and so on. The m^{th} row of the other determinant is also best read from right to left, but is of simpler construction, namely,

., $(m-1)_2$, $(m-1)_2$, $(m-1)_1$, $(m-1)_1$, $(m-1)_0$, $(m-1)_0$,
 duplication occurring in the case of each combinatory number as a whole.

RONDEBOSCH, S.A.,
 January 1, 1919.

NOTE ON CERTAIN DETERMINANT IDENTITIES ARRIVED
AT BY H. v. KOCH.

BY SIR THOMAS MUIR, LL.D.

(1) In Koch's first paper on the solution of an infinite set of linear equations,* he devotes a section (§2, pp. 114-117) to the establishment of certain identities which he required for use in connection with the main subject of his investigation. These identities, for some reason—probably because of the medium of publication, or because the title of the paper gave no indication of them—have not received from students of determinants the attention which they deserved.

(2) The first of them appears as a deduction from the solution of two sets of linear equations, namely, the set

$$a_{r1}x_1 + a_{r2}x_2 + \dots + a_{rn}x_n = u_r \quad \left. \vphantom{a_{r1}x_1 + a_{r2}x_2 + \dots + a_{rn}x_n = u_r} \right\}_{r=1}^{r=n}$$

and the set

$$a_{r1}x_1 + a_{r2}x_2 + \dots + a_{rn}x_n + a_{r,n+1}x_{n+1} = u_{r+1} \quad \left. \vphantom{a_{r1}x_1 + a_{r2}x_2 + \dots + a_{rn}x_n + a_{r,n+1}x_{n+1} = u_{r+1}} \right\}_{r=1}^{r=n+1}$$

which are seen to be so related that the first set may be viewed as formable from the second by striking out from the latter the last equation and the last term of all the other equations. In the case of two sets of equations so related, it is clearly necessary to be able to distinguish between the value of an x in the one set and the value of the same x in the other set. Let us therefore denote by

$$(x_p)_n$$

the value of x_p in the n -line set of equations; we can then assert that Koch's first subject for inquiry is

$$(x_p)_{n+1} - (x_p)_n,$$

and that his initial lemma is

$$(x_p)_{n+1} - (x_p)_n = (-1)^{n-p+1} \cdot \frac{C_p^{(n-p+1)}}{\Delta_n} \cdot (x_{n+1})_{n+1}$$

where

$$\Delta_n = |a_{11} \dots a_{nn}|,$$

* "Om upplösningen af ett system lineära likheter mellan ett oändligt antal obekanta," 'Öfversigt af K. Vetenskaps-Akad. Förhandl.' (Stockholm), xlvii, pp. 109-129.

(6) Returning to (X), and recalling that

$$\frac{V_q}{\Delta_q} \text{ stands for } \frac{\begin{vmatrix} a_{11} & \dots & a_{q-1, q-1} u_q \end{vmatrix}}{\begin{vmatrix} a_{11} & \dots & a_{qq} \end{vmatrix}}, \text{ i. e. for } (x_q)_q,$$

we readily transform the equality into

$$(x_p)_n = (x_p)_p - \frac{C_p^{(1)}}{\Delta_p} (x_{p+1})_{p+1} + \frac{C_p^{(2)}}{\Delta_{p+1}} (x_{p+2})_{p+2} - \dots + (-1)^{n-p} \frac{C_p^{(n-p)}}{\Delta_{n-1}} (x_n)_n.$$

A second simplification is effected by using for Δ_q the notation $|a_{1q}|$, which needs no definition; and a third would be got if the C's could be replaced by something more readily recalling the fact that $C_p^{(r)}$ is the minor of Δ_{p+r} got by deleting the last row and the p th column, or the minor got by differentiating Δ_{p+r} with respect to $a_{p+r, p}$. The symbols

$$|a_{1, p+r}|_{p+r, p}, \quad |a_{1, p+r}|'$$

suggest themselves for this, and, adopting the first, we obtain

$$(x_p)_n = (x_p)_p - \frac{|a_{1, p+1}|_{p+1, p}}{|a_{1p}|} (x_{p+1})_{p+1} + \frac{|a_{1, p+2}|_{p+2, p}}{|a_{1, p+1}|} (x_{p+2})_{p+2} - \dots + (-1)^{n-p} \frac{|a_{1n}|_{n, p}}{|a_{1, n-1}|} (x_n)_n,$$

which is readily seen to contain nothing but determinants, ranging from the p th order to the n th, and all of them minors of the array

$$\begin{array}{cccccc} a_{11} & \dots & a_{1n} & u_1 \\ & \dots & & \dots \\ a_{n1} & \dots & a_{nn} & u_n. \end{array}$$

Also, the same must be true of (Y) and (Z), since the only fresh symbol appearing in these equalities is $B_{p, n}$, which we have seen defined as a minor of $|a_{1n}|$; in fact, the array with which (Y) and (Z) are concerned has one column fewer than the previous array, being the array of $|a_{1n}|$.

(7) Having these facts in view, one naturally asks how (X), (Y), (Z) can be established by using merely the properties of determinants; and clearly a helpful reply is possible when one recalls that particular instances of the case of (X) where p is 1, namely, the case

$$\frac{u_1 a_{22} \dots a_{nn}}{a_{11} a_{22} \dots a_{nn}} = \frac{u_1}{a_{11}} - \frac{a_{12} |a_{11} u_2|}{a_{11} |a_{11} a_{22}|} + \frac{|a_{12} a_{23}| |a_{11} a_{22} u_3|}{|a_{11} a_{22}| |a_{11} a_{22} a_{33}|} - \dots$$

have more than once turned up in past work, and been proved in the way desired. One such case, for example, has been used by Kronecker* and another by Glaisher.† Further, in regard to the latter, there is on

* 'Monatsb. Akad. d. Wiss.' (Berlin), Jahrg. 1874, pp. 214-5.

† 'Monthly Notices R. Astron. Soc.', xxxiv (1874), pp. 311-334.

record* the suggestion that "a very instructive way of establishing it is to combine the first two terms on the right into one, then in similar manner combine the result thus obtained with the third term, and so on. The series is thus seen to be one of those that close up telescopically." Various procedures are thus open for trial. Suffice it to say that the last method is found to be as easily applicable to the general result (X) as to Kronecker's and Glaisher's cases.

(8) The inquiry about the said cases, however, led to the very interesting discovery that (X) in all its generality was published by Schweins† so long ago as 1825 in his 'Theorie der Differenzen und Differentiale,' Sect. I, Chap. V. With Schweins the theorem is purely determinantal, the determinants being written in a kind of elaborate umbral notation, bulky but not ambiguous.

(9) The second equality (Y) is provable exactly like (X), but the application of the method brings out the unexpected fact that the two theorems are not really different, the second being, indeed, merely a case of the first. To convince oneself of this, one has only to take (X), which, as we have seen, is an equality concerning the array

$$\begin{array}{ccccccc} a_{11} & \dots & a_{1n} & u_1 & & & \\ & & & & & & \\ & & & & & & \\ a_{n1} & \dots & a_{nn} & u_n & & & \end{array}$$

and change the column of u 's into a column of a 's, namely, into the m th column where $m > p$ and $\bar{m} \leq n$. The left-hand member of (X) then vanishes, and the right-hand member becomes

$$K_{pp}B_{pm} + K_{p,p+1}B_{p+1,m} + \dots$$

and thus we have (Y).

(10) Lastly, turning our scrutiny on to (Z), we find an outcome equally unexpected but of a different kind. The K 's, which were introduced "for shortness' sake," do not here at all serve their purpose, for on replacing them in (Z) by their equivalents we obtain

$$\begin{aligned} & (-1)^{m-p} \frac{C_p^{(m-p)} B_{pp}}{\Delta_{m-1} \Delta_m} + (-1)^{m-p-1} \frac{C_{p+1}^{(m-p-1)} B_{p,p+1}}{\Delta_{m-1} \Delta_m} + \dots \\ & \dots + \frac{C_m^{(0)} B_{mm}}{\Delta_{m-1} \Delta_m} = 0 \end{aligned}$$

from which manifestly the Δ 's can be struck out. This being done, the equality then to be considered is in Koch's own notation

$$C_p^{(m-p)} B_{pp} - C_{p+1}^{(m-p-1)} B_{p,p+1} + C_{p+2}^{(m-p-2)} B_{p,p+2} - \dots = 0,$$

* 'Proc. R. Soc. Edinburgh,' xxxiii, p. 61.

† Muir, T., "An Overlooked Discoverer in the Theory of Determinants," 'Philos. Mag.' (5) xviii, pp. 416-427; or 'Hist.' I, pp. 173-4.

and we have only to think of the determinants, which the C's and B's represent, to recognise the result as a familiar theorem regarding an aggregate of products of pairs of determinants often associated with Sylvester's name, but dating much farther back in the history of the subject.

(11) Although Koch's identities are thus seen to be rediscoveries, it is equally clear that his method of arriving at them is his own, and is well worthy of study.

RONDEBOSCH, SOUTH AFRICA,
March 9th, 1919.

SOUTH AFRICAN PERISPORIACEAE.

BY ETHEL M. DOIDGE.

(With Plate IV.)

(Read May 15, 1918.)

III. NOTES ON FOUR SPECIES OF *Meliola* HITHERTO UNRECORDED FROM SOUTH AFRICA.

The fungi under consideration are all from Natal and the eastern part of the Cape Province, and have been identified from recent collections.

Meliola malacotricha Speg. has been recorded from South America on Leguminosae, and has now been collected on plants belonging to this family in two localities in Natal.

M. bicornis Wint. is also recorded as occurring commonly on Leguminosae. The type specimen was collected in the island of S. Thomé, and later it was found in South America. Stevens in his monograph on 'The Genus *Meliola* in Porto Rico' states that numerous collections of this species have been made in Porto Rico, all on plants belonging to the same family.

The only record which I can find of its occurrence on a non-leguminous plant is in 'Le Genre *Meliola*' (Gaillard), where it is stated that a variety occurs on *Croton* sp. The present specimen, which agrees in every particular with the description, and which has been carefully compared with Winter's specimen (Fung. Eur. No. 3545), is on the leaves of *Oncinotis inandensis*, a plant belonging to the natural order Apocynaceae.

M. palmicola Wint. appears to be a species with a very wide distribution; it was first collected in Tonkin, and has subsequently been found on various palms in America and in India (Syd. Ann. Myc. xi, p. 382).

M. geniculata Syd. & But. was described as occurring on *Odina Wodier* in India. The South African specimen on *Rhus* spp. has somewhat larger perithecia, hyphopodia and spores than are called for by the description, in the size of the spores approaching more nearly to *M. Butleri*; but the form of the hyphopodia and the character of the setae correspond exactly with those described and illustrated for *M. geniculata*.

The South African specimens also occur on hosts of the same family as *Odina Wodier* on which the type-specimen occurs.

I have therefore described the former as a variety of *M. geniculata*.
The descriptions of these fungi are as follows:

Meliola malacotricha Speg.

Sacc. Syll. Supp. Univ. i, p. 425.

Gaillard, Le Genre *Meliola*.

Mostly hypophyllous, forming round or irregular spots 1-4 mm. diam., often confluent and covering a great part of the leaf surface. Hyphae brown, 5-7 μ thick; composed of cells 25-30 μ long; branches opposite; capitate hyphopodia opposite, alternate or unilateral, 14-16 \times 7-10 μ , briefly stipitate, terminal cell ovoid or globular; mucronate hyphopodia interspersed with the capitate hyphopodia, opposite, narrow-ampulliform, 12-15 μ long. Mycelial setae fairly numerous, incurved and bent at right angles at the base or at some other point in their length, becoming insensibly narrower towards the translucent apex, 150-300 \times 5-10 μ . Perithecia in small groups in the centre of the spot, globular, then depressed, black, minutely verrucose, 150-220 μ diam. Asci 2-spored. Spores 4-septate, cylindrical, straight or slightly curved, slightly constricted at the septa, and slightly attenuated towards the rounded extremities, 30-38 \times 12-15 μ .

On *Indigofera* sp., Buccleuch, Natal, 23/3/16, E. M. Doidge (9703).

On *Baphia racemosa*, Sea View, Durban, 1/10/17, P. v. d. Bijl (Natal Herbarium No. 783) (11354).

In both these specimens the majority of the spores fall within the dimensions given above, but a few are longer, up to 42 μ .

Meliola bicornis Wint.

Gaillard, Le Genre *Meliola*, p. 99.

Colonies black round-irregular, scattered or confluent, sometimes up to 8 mm. diam. Hyphae slender, 6-7 μ , spreading, laxly branched, flexuose, somewhat torulose. Capitate hyphopodia opposite, alternate or unilateral, small 12-15 μ \times 7-10 μ ; basal cell very short, 3-5 μ , enlarged at the base, terminal cell globular. Mucronate hyphopodia interspersed with the capitate hyphopodia, usually opposite, ampulliform, drawn out into rather a long neck. Mycelial setae rather numerous, slender, brown, translucent, with numerous septa, divided at the apex into 2 (occasionally 3) simple or forked acute branches. Perithecia scattered over the whole colony, globular, then depressed, scabrous, 120-160 μ diam. Asci ellipsoid with a very short foot, with 2-3 or 4 spores. Spores 4-septate, slightly constricted at septa, brown, broadly rounded at both ends, 37-45 \times 12-15 μ .

On leaves of *Oncinotis inandensis*, Buccleuch, Natal, 23/3/16, E. M. Doidge (9722).

Meliola palmicola Wint.Gaillard, Le Genre *Meliola*, p. 101

Spots orbicular, often confluent, 1–15 mm. diam., black, with an irregular margin. Mycelium brown, branching, branches opposite, anastomosing. Hyphae somewhat sinuous, about $10\ \mu$ thick, cells $24\text{--}28\ \mu$ long. Capitate hyphopodia alternate, stipitate, basal cell $10\text{--}25\ \mu$ long, non-septate in younger parts of mycelium and about $10\ \mu$ long, in central parts of colony often pluricellular and up to $25\ \mu$ long; terminal cell globular to ovoid, often bent laterally and more or less lobed, $16\text{--}20 \times 10\text{--}11\ \mu$. Mucronate hyphopodia fairly numerous, on separate branches, opposite, ampulliform, $17\text{--}20 \times 8\text{--}10\ \mu$. Mycelial setae very numerous, straight, erect, opaque, black, $400\text{--}500\ \mu$ long, about $10\ \mu$ thick at base, tapering slightly towards apex; apex sometimes simple, more often divided into 2–3 simple or bifid branches; more rarely there are 4 or 5 unilateral branches. Perithecia fairly numerous in centre of colony, globular, than depressed, $180\text{--}250\ \mu$ diam., surface minutely verrucose. Asci ovoid, 2–4 spored, about $54\text{--}56 \times 30\text{--}35\ \mu$. Spores 4-septate, slightly constricted at the septa, elliptic, rounded at both ends, $48\text{--}55 \times 20\text{--}22\ \mu$.

On both faces of leaves of *Phoenix reclinata*, Kentani, 29/11/15; Miss A. Pegler, M.H. (9170) (Pegler No. 2372).

On leaves of *Phoenix* sp., Port Shepstone, Natal, 15/10/12, I. B. Pole (Evans 5607).

Meliola geniculata Syd. & Butl.

Annales Mycologici, Bd. ix, 1911, p. 381.

var. *macrospora* var. nov.

Mycelium mostly epiphyllous, thin, spreading, black, effuse, not forming definite spots, often following the primary veins of the leaf. Hyphae fuscous, septate, $5\text{--}7\ \mu$ thick; branches mostly alternate; cells of hyphae, $20\text{--}36\ \mu$ long, mostly $20\text{--}25\ \mu$. Capitate hyphopodia alternate, $16\text{--}24\ \mu$ long, basal cell minute, capitate cell clavate, $10\text{--}12\ \mu$ broad. Mucronate hyphopodia opposite or unilateral up to $20\ \mu$ long; narrowing above and often curved. Mycelial setae scattered, often more numerous around perithecia, $200\text{--}275\ \mu$ long, $5\text{--}8\ \mu$ thick, not tapering towards apex, abruptly geniculate near base, with 2–5 incisions or teeth on the blunt apex; more or less translucent. Perithecia scattered, few, globose, tuberculate, black, $180\text{--}240\ \mu$ diam. Asci ovate, very briefly stipitate, 2-spored. Spores oblong or oblong-cylindrical, constricted at the septa, rounded at both ends, brown or fuscous, $40\text{--}43 \times 16\text{--}18\ \mu$.

On leaves of *Rhus dentata*, 21/3/16, Town Bush Valley, Maritzburg, Natal, E. M. Doidge (9716).

On leaves of *Rhus tomentosa*, 13/11/17, Van Staden's Pass, C.P., E. M. Doidge (10879).

Meliola geniculata Syd. & Butl.

var. *macrospora* var nov.

Hyphopodiis capitatis $16-24\ \mu \times 10-12\ \mu$; peritheciis $180-240\ \mu$ diam.; sporidiis $40-43\ \mu \times 16-18\ \mu$.

A typo differt, hyphopodiis capitatis, peritheciis et sporidiis majoribus.

EXPLANATION OF PLATE IV.

[All drawings made with help of camera lucida, with Zeiss objective DD and ocular No. 5.]

FIG.

1. *Meliola malacotricha*. (a) Mycelium showing capitate and mucronate hyphopodia; (b) spores.
2. *Meliola bicornis*. (a) Mycelium with capitate and mucronate hyphopodia; (b) spores; (c) tips of mycelial setae.
3. *Meliola palmicola*. Mycelium with (a) capitate and (b) mucronate hyphopodia; (c) spores; (d) tips of mycelial setae.
4. *Meliola geniculata* var. *macrospora*. Mycelium with (a) capitate and (b) mucronate hyphopodia; (c) spores; (d) tips of mycelial setae.

BOTANICAL LABORATORIES OF THE UNION
OF SOUTH AFRICA, PRETORIA.

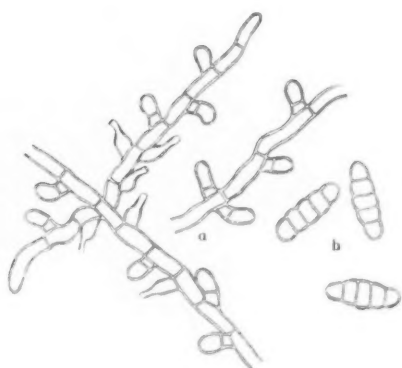


FIG. 1.

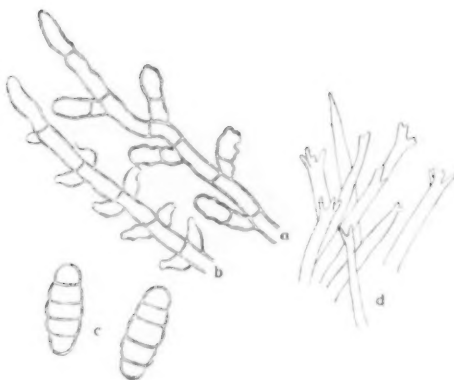


FIG. 3.

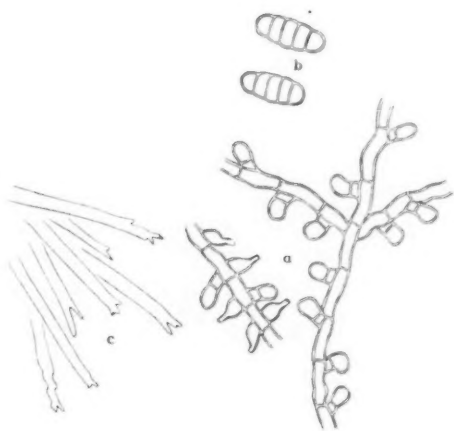


FIG. 2.

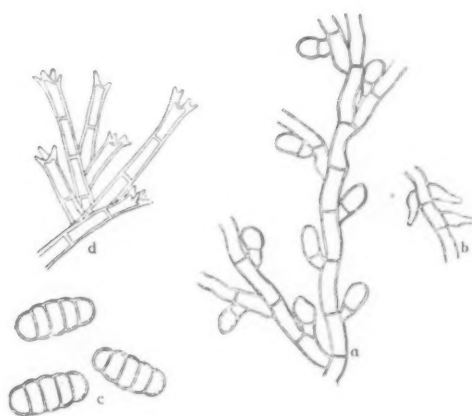


FIG. 4.

SOUTH AFRICAN PERISPORIACEAE.

BY ETHEL M. DOIDGE, M.A., D.Sc., F.L.S.

(With Plates V and VI.)

(Read June 19, 1918.)

IV. NEW SPECIES FROM THE COAST DISTRICTS.

Of the nine new species of fungi described below, six belong to the genus *Meliola*, of which forty-two species have now been recorded as occurring in South Africa.

Meliola Evansii is closely related to *M. ganglifera*, from which it differs chiefly in the size of the spores and in the size and form of the hyphopodia.

The section characterised by the presence of perithecial appendages is a comparatively small one, and up to the present only one species has been described—*M. Bosciae*, from the Natal coast. Three more species belonging to the section have now been collected, and these may be distinguished by the following characters:

Section II, n: Spores 4-septate, setae perithecial.

a. Spores less than $40\ \mu$ long.

x. Setae straight, *M. Kentaniensis*.

xx. Setae uncinata, *M. claviculata*.

b. Spores $40\text{--}50\ \mu$ long.

x. Spores $10\text{--}14\ \mu$ broad, *M. Bosciae*.

xx. Spores $15\text{--}17\ \mu$ broad, *M. comata*.

The two remaining species belong to the large section with 4-septate spores and simple mycelial setae.

M. Lozostylidis is closely allied to *M. Rhois*, from which it differs in the form and number of the mycelial setae. *M. Cryptocaryae* comes nearest to *M. microthecia*, but is distinguished from that species by the larger size of the perithecia and by other minor differences.

Meliola comata Doidge n. sp.

Amphigena, plerumque epiphylla, maculas atras, 1–3 mm. diam. efficiens; hyphis fuscis, subflexuosis, $7\text{--}8\ \mu$ crassis; ramis plerumque oppositis; hyphopodiis capitatis alternis, stipitatis, $18\text{--}25 \times 9\text{--}10\ \mu$, cellula basali $4\text{--}6\ \mu$ longa, prope hypham attenuata, cellula superiore ovata v. angulata; hyphopodiis

mucronatis oppositis v. unilateralibus, inter hyphopodias capitatas interspersis, piriformibus v. ampullaceis, saepe curvatis, $18-20 \times 6-7 \mu$; setis mycelicis nullis; setis perithecialibus numerosis (circ. 20), $100-150 \mu$ long., basi brunneis, 6μ crassis, ad apicem pellucidem, 3μ cr. attenuatis; plerumque plus minusve incurvatis, et nonnumquam uncinatis, non-septatis; peritheciis gregariis, atris, globulosis, carbonaceis $200-240 \mu$ diam., verrucosis; ascis bisporis, evanescentibus; sporidiis cylindraceis brunneis, 4-septatis, vix constrictis, leniter utrinque attenuatis, $40-43 \times 15-17 \mu$.

In foliis ? *Ipomeae* sp. Woodville Forest, George, 15/11/17, E. M. Doidge (11020).

This fungus is very much overgrown by a number of parasites, chiefly *Dimerium intermedium*, *Speggazinia* sp., and an ascomycete with thyriothecia of the Microthyriaceae type which is frequently found parasitic on various species of *Meliola*, but up to the present always in an immature condition.

Meliola Cryptocaryae Doidge n. sp.

Hypophylla, maculas rotundas v. enormes, $4-10 \mu$ diam. efficiens; hyphis undulatis, $6-7 \mu$ crassis; ramis oppositis v. irregularibus, cellulis $20-30 \mu$ longis; hyphopodiis capitatis alternis, breviter stipitatis, $26-33 \times 8-10 \mu$, tenuibus, undulatis, uncinatis v. sub-lobatis, cellula basali $6-7 \mu$ long.; hyphopodiis mucronatis oppositis pallidioribus, ampullaceis, curvatis, $15-16 \mu$ long.; setis mycelicis paucis, sparsis, sed circum perithecia numerosis, rectis v. sub-flexuosis, basin abrupte geniculatis, $400-500 \mu$ longis, opacis, $6-7 \mu$ crassis, paulatim ab imis ad apicem pellucidem, 3μ cr. attenuatis; peritheciis gregariis, atris, globosis, verrucosis, $240-260 \mu$ diam.; ascis bisporis evanescentibus; sporidiis 4-septatis cylindraceis, leniter constrictis, utrinque sub-attenuatis rotundatis que, $50-57 \times 18-20 \mu$.

In foliis *Cryptocaryae latifoliae*, Umbilo, Natal, 29/10/16, leg. P. van der Bijl (N. H. 517) (11016); Stella Bush, Durban, January, 1917, P. v. d. Bijl (N. H. 518).

In foliis *Cryptocaryae Woodii*, Mayville, Natal, 22/7/15, leg. J. Medley Wood (9025).

The mycelium is more undulate, and the setae more wavy in the collections on *C. latifolia* than in those on *C. Woodii*. This is probably to be attributed to the tomentose under-surface of the leaves in the former species. On *C. Woodii* the setae are as a rule quite straight.

Meliola Evansii Doidge n. sp.

Amphigena, plerumque epiphylla, maculas atras rotundas, 3-5 mm. diam. efficiens: mycelio conferto, copiose ramoso, anastomosante; hyphis brunneis $6-8 \mu$ diam.; cellulis circ. 20μ long.; ramis alternis, ad articulas cum hyphis abrupte attenuatis; hyphopodiis capitatis alternis, stipitatis, $26-36 \times 13-16 \mu$, cellula basali $8-10 \mu$ long.; ad articulum cum hypha

abrupte attenuata, cellula superiore cylindrica, uncinata, v. ovata, irregulariter lobulata; hyphopodiis mucronatis pallidioribus, haud numerosis, piriformibus, ca. $20 \times 7 \mu$; setis mycelicis sparsis, satis numerosis, rectis, simplicibus, opacis $300-400 \mu$ long., $7-8 \mu$ cr., ad apicem pellucidem paulatim attenuatis; peritheciis sparsis, haud numerosis, atris, globosis, carbonaceis, verrucosis, $200-240 \mu$ diam.; ascis bisporis, evanescentibus; sporidiis brunneis, 3-septatis, constrictis, sub-curvatis, cellulis mediis majoribus, $48-54 \times 18-20 \mu$.

In foliis *Celastrineae* cujusdam, Mossel Bay, 22/7/15, leg. I. B. Pole Evans (9067), in foliis *Mystrozydon euclaeformis*, Qudeni Forest, Zululand, leg. G. W. Davies (11237); Woodbush, Zoutpansberg Dist., February, 1914, leg. A. J. O'Connor (Economic Herb. No. 10222).

M. gangliferae affinis.

Meliola Kentaniensis Doidge n. sp.

Amphigena, plerumque epiphylla, maculas atras 3-5 mm. diam. efficiens; hyphis brunneis, subflexuosis, $5-7 \mu$ crassis, cellulis $18-23 \mu$ long.; ramis oppositis; hyphopodiis capitatis alternis v. unilateralibus, $15-20 \times 8-10 \mu$, brevissime stipitatis, cellula basali circ. 3μ long., et 6μ cr.; cellula superiore, irregularis, plerumque ovata sed plus minusve angulata tuberculataque; hyphopodiis mucronatis non numerosis, inter hyphopodias capitatas interspersis, ampullaceis, collo longo curvato, $15-17 \times 6-8 \mu$; setis mycelicis nullis; setis perithecialibus $5-12$, rectis v. leniter flexuosis, pellucidis, leniter attenuatis ad apicem obtusum, basim sub-bulbosis, septatis, $60-90 \times 5-7 \mu$; peritheciis atris, carbonaceis, globosis, verrucosis, $160-200 \mu$ diam.; ascis evanescentibus; sporidiis 4-septatis, brunneis, cylindraceis, utrinque rotundatis, leniter constrictis, $35-38 \times 14-16 \mu$.

In foliis ? *Rhus* sp. Kentani, C.P., 6/9/15, leg. A. Pegler (Pegler No. 2354) (9130).

Meliola claviculata Doidge n. sp.

Amphigena, maculas minutas, atras, creberrimas efficiens, superficiem foliae tecta; hyphis brunneis, undulatis, $6-7 \mu$ crassis; cellulis brevibus, $12-15 \mu$ long.; hyphopodiis capitatis alternis, breviter stipitatis, $17-20 \times 8-10 \mu$, saepe ad hyphas appressis, cellula basali $3-5 \mu$ long.; cellula superiore subovata, plerumque apice complanata; hyphopodiis mucronatis oppositis, ampullaceis, curvatis $14-20 \times 6-7 \mu$; setis mycelicis nullis; setis perithecialibus $3-7$, omnino pellucidis, non-septatis, $100-120 \times 6-7 \mu$, apice haud attenuatis, uncinatis v. contortis; peritheciis gregariis, atris, globulosis, verrucosis, $206-230 \mu$ diam.; ascis bisporis, evanescentibus; sporidiis 4-septatis, cylindraceis, loculis aliquanto irregularibus, leniter constrictis, $36-40 \times 15-18 \mu$.

In foliis *Oncobae* sp. Quelimane, Portuguese East Africa, 8/9/13, leg. I. B. Pole Evans (7388).

Meliola Loxostylidis Doidge n. sp.

Hypophylla, maculas atras 3–4 μ diam. efficiens; hyphis tortuosis, fuscis, torulosis, 5–9 μ crassis; ramis irregularibus, anastomosantibus; hyphopodiis capitatis alternis v. plerumque unilateralibus, stipitatis, 20–30 \times 10–17 μ , cellula basali rectis v. curvatis, 10–17 \times 5–7 μ , cellula superiore ovata, uncinata v. triangularis; hyphopodiis mucronatis non numerosis, oppositis alternis v. unilateralibus, pyriformibus, 13–17 \times 6–7 μ ; setis mycelicis raris, simplicibus, rectis v. basim abrupte geniculatis, omnino pellucidis, haud apice acuto attenuatis, nonnunquam ad septa constrictis, 140–240 μ long., 6–7 μ crassis; peritheciis non numerosis, sparsis, atris, globosis, carbonaceis, verrucosis, 200–240 μ diam.; ascis 2–4 sporis, evanescentibus; sporidiis 4-septatis, cylindraceis, compressis, vix constrictis, utrinque rotundatis 37–47 \times 17–20 μ .

In foliis *Loxostylidis alatae*, van Stadens Pass, C.P., 13/11/17, leg. E. M. Doidge (10921).

In foliis fruticis incognitis, 22/7/15, Mayville, Natal, leg. J. Medley Wood (9026).

Zukalia parenchymatica Doidge n. sp.

Epiphylla, effusa, pelliculam tenuem, fuscam efficiente mycelio pallidiore, fuliginoso, hyphis 3.5–5 μ cr., copiose ramosis anastomosantibus; cellulis 10–15 μ long.; hyphis ad septa constrictis, pelliculam plecten chymaticam, praesertim prope perithecia efficientibus; peritheciis globuloso-depressis, deinde pulvinatis; sparsis, parenchymaticis, membranaceis, 300–400 μ diam.; ascis numerosis paraphysatis, ellipsoideis-ovatis breviter pedicellatis, 50–60 \times 20–30 μ ; paraphysibus filiformis, ascos parum superantibus; sporidiis oblique distichis v. conglobatis hyalinis v. flavescentibus, 5–7 septatis, ellipsoideis nonnunquam sub-curvatis, ad septa vix constrictis, 30–40 \times 8–10 μ .

In foliis *Xymalos monosporae* Kentani, 3/3/15, leg. A. Pegler (Pegler No. 1999) (8864).

Zukalia Woodiana Doidge n. sp.

Hypophylla, maculas ferrugineae 10–15 μ diam. efficiens; mycelio pallidiore, fuligineo; hyphis tenuibus, circ. 3 μ crassis, copiose ramosis, anastomosantibus; hyphopodiis nullis; peritheciis numerosis, atris, sub-globosis, carbonaceis, verrucosis, pseudo-ostiolatis 95–115 μ diam.; ascis 8-sporis, aparaphysatis, ellipsoideis v. ovatis, breviter pedicellatis, apice tunicatis 30–40 \times 13–17 μ ; sporidiis hyalinis-flavescentibus, distichis v. parallelis, linearis-ellipsoideis v. sub-clavatis; primo sub-equaliter 1-septatis, deinde 3–5 septatis, medio facile divisus, 18–24 \times 4–5 μ .

In foliis *Celastris albat*i, 20/5/15, Winkle Spruit, Natal, leg. E. M. Doidge (9008).

In foliis *Celastrineae* cujusdam, 22/7/15, Durban, Natal, leg. J. Medley Wood (9061).

Phaeodimeriella asterinicola Doidge n. sp.

Peritheciis in mycelio *Asterinae* quaedam parasiticis, hyphis parvissime 3-3.5 μ cr. evolutis, aggregatis, ovatis usque globosis, atris, membranaceis, superne angustatis papilliformiter productis et poro pertusis, 70-100 μ diam., setis 4-10 coronatis; setis 40-50 μ long., brunneis, apice obtusis et sub-uncinatis v. curvatis; ascis fasciculatis, numerosis, paraphysatis, clavato-cylindraceis, sessilibus, 8-sporis, 40-45 \times 10-12 μ ; sporidiis distichis, subfusiformibus, 1-septatis haud v. vix constrictis, loculo supero plerumque latiore, 13-14 \times 3.5-5 μ .

Parasitic in *Asterina* quadam ad folia *Tylophorae Flanaganii*, 14/8/15, Brander's High Forest, Victoria East C.P., leg. P. v. d. Bijl (9458).

EXPLANATION OF PLATES V AND VI.

[All drawings were made with the aid of the camera lucida with a Zeiss objective DD and No. 5 ocular.]

FIG.

1. *Meliola comata*. (A) Mycelium with capitate and mucronate hyphopodia; (B) perithecial setae; (C) spores; (D) superficial cells of the perithecium.
2. *M. Cryptocaryae*. (A) Mycelium with capitate hyphopodia; (B) mycelium with mucronate hyphopodia; (C) spores.
3. *M. Evansii*. (A) Mycelium with capitate hyphopodia; (B) mucronate hyphopodium; (C) spores; (D) superficial cells of perithecium.
4. *M. Kentaniensis*. (A) Mycelium with capitate hyphopodia; (B) mucronate hyphopodia; (C) spores; (D) perithecial setae.
5. *M. claviculata*. (A) Mycelium with capitate hyphopodia; (B) with both capitate and mucronate hyphopodia; (C) spores; (D) superficial cells of perithecium; (E) perithecial setae.
6. *Meliola Loxostylidis*. (A) Mycelium with capitate hyphopodia; (B) with mucronate hyphopodia; (C) spores; (D) superficial cells of perithecium.
7. (A) Spores of *Zukalia parenchymatica*; (B) spores of *Z. Woodiana*; (C) spores, and (D) mycelial setae of *Phaeodimeriella asterinicola*.

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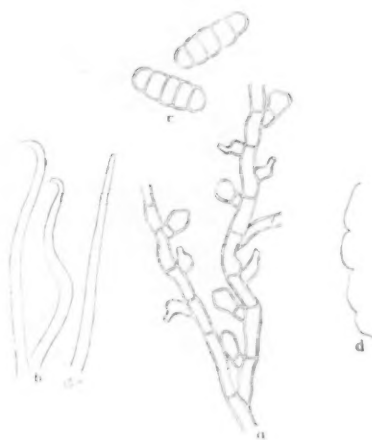


FIG. 1.

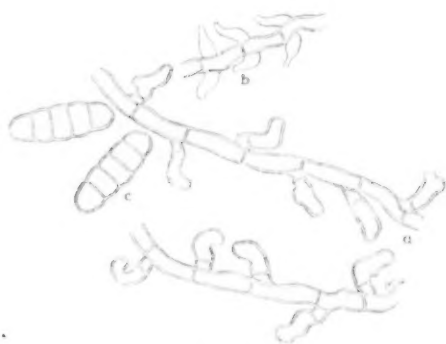


FIG. 2.

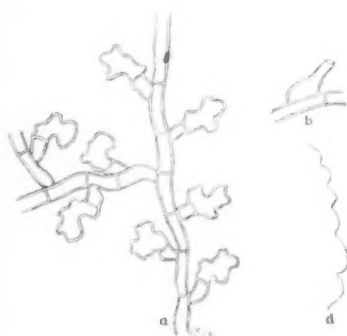


FIG. 3.

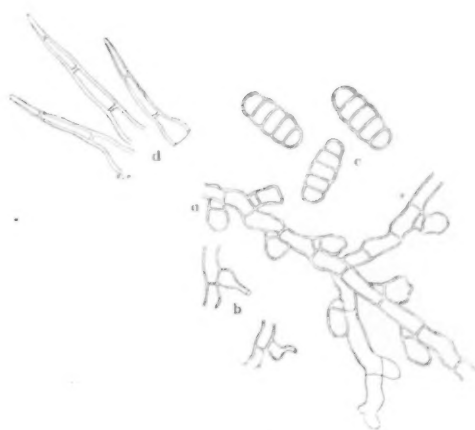


FIG. 4.

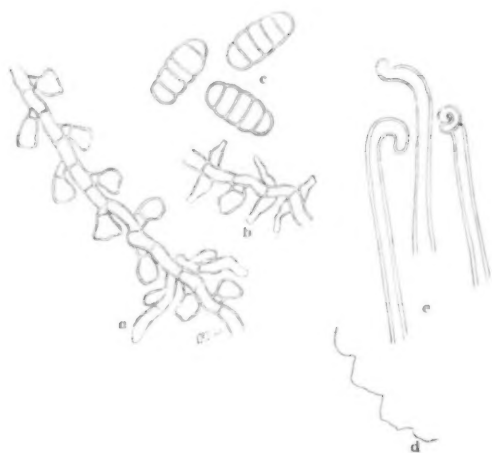


FIG. 5.

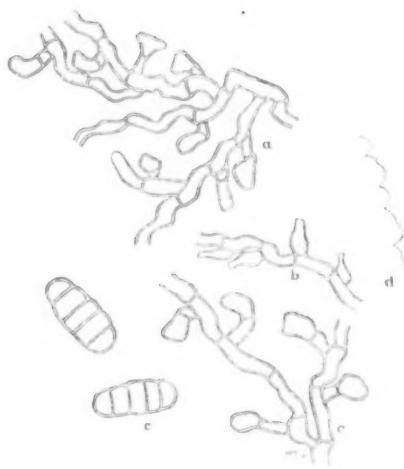


FIG. 6.



FIG. 7.

MYCOLOGICAL NOTES.—I.

BY ETHEL M. DOIDGE.

(Read July 17, 1918.)

Asterodothis solaris Kalch & Cke.

In 'Grevillea,' vol. ix, p. 33, *Asterina solaris* K. & Cke. was described as occurring on *Olea verrucosa*, from a specimen collected by MacOwan. Theissen (Ann. Myc. x, p. 179) has recently shown that this fungus is identical with *Lembosia Albersii* P. Henn (Bot. Jahrb. xxviii, p. 39) on *Elaeodendron* sp. collected in East Africa, and with *Seynesia elegantula* Syd. (Engl. Bot. Jahrb. 1910, p. 263; Massai-Hochland, Afrika) collected on *Xymalos* sp. He has also pointed out that the fungus cannot be placed on the *Microthyriaceae*, as the stroma originates under the epidermis; and he describes the new genus *Asterodothis* as belonging to the *Dothideaceae*.

This specimen, collected by MacOwan on *Olea verrucosa*, therefore becomes *Asterodothis solaris* (K. & Cke.) Th. Judging by the number of collections in the Union Government Herbarium this fungus occurs very commonly and is very wide-spread in South Africa. It has been found not only on various species of *Olea*, but also on one of the hosts on which it was found in East Africa.

The following is a list of the material collected up to the present:

On *Olea verrucosa* leg. MacOwan (3991), Wellington, C.P., E. M. Doidge (1032); Barberton, Transvaal, 22/2/15, G. Thorncroft (8826); Port Elizabeth, 17/10/07, Miss E. West (1870).

On *Olea laurifolia*, 10/3/15, Fort Cunninghame (8896).

On *Olea Woodiana*, 24/11/17, East London, E. M. Doidge (10902); Victoria East, P. v. d. Bijl (9464).

On *Olea exasperata*, Belmont Valley, Grahamstown, 15/11/17, E. M. Doidge (10955).

On *Olea* sp., Hogg's Back, 15/1/18, J. & M. Henderson (11339).

On *Eugenia* sp., Paddock, Natal, 22/12/13, P. v. d. Bijl (8375).

On *Myrsine melanophleas*, Claridge, Natal, 31/5/15, E. M. Doidge (8995) East London, 24/11/17, E. M. Doidge (10908).

On *Elaeodendron capense*, Grahamstown, 13/12/11, J. Burt-Davy (2070).

On *Elaeodendron croceum* Knysna, 3/6/12, P. J. Pienaar (2435).

The genus *Asterodothis* is described by Theissen as "affine *Dothidasteromellae* v. Höhn." The latter genus is represented in this country by a species described by Sydow ('Ann. Myc.' x, p. 41), *Dothidasteromella orbiculata* Syd. on the leaves of *Olea verrucosa* (1031).

A nearly related species has now been collected in the Cape forests on the leaves of *Trichocladus ellipticus*.

Dothidasteromella contorta Doidge n. sp.

Stromatibus epiphyllis, sparsis, orbicularibus v. irregularibus, atris, carbonaceis, 2-3 mm. diam., erumpenti superficialibus; hyphis, aliis longiusculis, radiantibus, fuscis, 3-3.5 μ crassis, hyphopodiis alternis v. unilateralibus, sub-globosis, continuis, 6-7 μ diam., aliis pallidioribus, torulosis, copiose ramosis anastomosantibus-que, dense intertextis cum hyphis radiantibus; peritheciis numerosis, opacis, superne poro medio dehiscentibus; ascis paraphysatis; ellipsoideis v. ovatis, brevissime stipitatis, rectis v. curvatis, 55-80 \times 20-25 μ ; paraphysibus numerosis, linearibus, flexuosis v. rugosis; sporidiis distichis v. conglobatis, medio 1-septatis, fuscis, leniter constrictis loculo-superiore latiore, 16-20 \times 8-10 μ .

Hab. in foliis *Trichocladii elliptici*, Branders High Forest, Victoria East, C.P. leg. P. v. d. Bijl (9462).

Speggazzinia meliolae A. Zimm.

Centralb. f. Bakt. II Abt., Bd. viii, 1902, p. 221.

Syll. Fung. xviii, p. 690.

This fungus, which was described as parasitic on *Meliola* sp. from Java, has not previously been recorded from this country. It is commonly found parasitic on various species of *Meliola*, and there is a heavy infection recorded on *Meliola claviculata* on *Oncoba* sp. Quelimane, Port. East Africa, 8/9/13, I. B. Pole Evans (10002).

Phaeosphaerella senniana Sacc.

Ann. Myc. viii, 1910, p. 337.

Sacc. Syll. Fung. xxii, p. 169.

The type specimen is on dying leaves of *Protea abyssinica* collected in Erythraea, North Africa. In the South African collections the perithecia are slightly larger than called for, but otherwise they agree exactly with the description. I can find no previous record of the occurrence of this fungus in South Africa. It has been collected from several localities and on three different species of *Protea* as follows:

On dying leaves of *Protea mellaleuca*, Wellington, C.P., 10/11/10, E. M. Doidge (1034); 22/2/12 (2062).

On dying leaves of *Protea acaulis*, Wellington, C.P., 12/11/10, E. M. Doidge (1022).

On dying leaves of *Protea abyssinica*, The Willows, Pretoria, 11/1/13, P. v. d. Bijl (5590).

An ascomycete collected on the stem of one of the large *Euphorbias*, growing along the river bank of the Amanzimtoti, appears to be an undescribed species of *Gloniella*. The ascospores are 15-septate; I have therefore named the fungus *Gloniella multiseptata*.

Gloniella multiseptata Doidge n. sp.

Peritheciis atris, carbonaceis, gregariis, erumpento-superficialibus linearibus-ellipsoideis, utrinque attenuatis, rotundatisque, rectis v. varie curvatis, 1-5 mm \times .25-.3 mm., rima longitudinali tenuissima percursis; ascis sub-clavatis v. cuneatis, rectis v. curvatis, paraphysatis, stipitatis, 8-sporis, 80-87 \times 17-20 μ ; paraphysibus numerosis, linearibus, ascos superantibus; sporidiis parallelis, anguste ellipsoideis v. sub-clavatis hyalinis, 15-septatis, rectis v. cub-clavatis 50-70 \times 6-8 μ .

In caulis *Euphorbiae triangularis*, Amanzimtoti, Natal, 20/5/13, E. M. Doidge (5624).

Isariopsis griseola Sacc.

This fungus, which is widely distributed in Europe, and which is reported from America as causing a leaf spot of the French bean (*Phaseolus vulgaris*), recently made its appearance in some experimental plots; it forms large dry brown areas on the leaves and causes them to drop prematurely. So far as I am aware this is the first time this fungus has been observed in S. Africa. It is chiefly interesting as one of the few plant parasites belonging to the group *Stilbaceae*, which consists for the most part of saprophytic and entomogenous fungi.

BOTANICAL LABORATORIES OF THE UNION
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MELIOLASTER, A NEW GENUS OF THE MICRO- THYRIACEAE.

By ETHEL M. DOIDGE.

(Read August 21, 1918.)

As a result of the work of re-examination and revision of certain ascomycetes carried out in recent years by v. Höhnelt and Theissen, the group formerly known as the *Perisporiales** has been entirely reorganised. It was laid down by v. Höhnelt† that only species showing the so-called "inverse-radial" structure of the perithecium should be included in the *Microthyriaceae*; a number of species with hemispherical perithecia but not showing this typical structure were thus excluded, and for these Theissen constituted the families *Hemisphaeriaceae*‡ and *Trichopeltaceae*§, the latter group consisting of forms with a thallus-like structure, and with fruiting bodies formed "pycnotically" in the thallus. The three families, *Microthyriaceae*, *Hemisphaeriaceae* and *Trichopeltaceae*, constitute the group *Hemisphaeriales*, and are thus contrasted with forms having spherical perithecia like the *Perisporiaceae*. In both groups certain genera, e. g. *Meliola* and *Asterina*, bear hyphopodia at regular intervals on the mycelium; the division into families is based only on the structure of the fruiting bodies, but mycelial characters are often used as generic distinctions.

This being the case it is interesting to find amongst fungi occurring in South African forests, species which appear to be intermediate in character, and in which are combined peculiarities of more than one family. The vegetative stage of the *Trichopeltaceae* consists of a flat ribbon or disc formed by the repeated branching of the constituent hyphae, which are fused by their lateral walls; the "pycnothecia," as the fruiting bodies are called, are hemispherical, and are formed in the vegetative membrane by the thickening of certain portions of it. This group thus forms a very complete contrast to fungi like the *Meliolas* which have a filamentous, spreading mycelium, and spherical perithecia which are quite a distinct development from the vegetative mycelium.

* Engler, 'Die Pflanzenfamilien.'

† v. Höhnelt, 'Fragm. z. Mijk.,' x, p. 13, ff.

‡ Theissen, 'Ann. Myc.,' xi (1913).

§ Theissen, 'Mycologische Centralb.,' iii, No. 6, pp. 273-286.

Meliola pellata,* a species found on *Podocarpus latifolia* and *P. falcata* (it does not to my knowledge occur on *P. elongata*), although its perithecia are spherical and its spores typical of the genus *Meliola*, in its vegetative stage strongly recalls the *Trichopeltaceae*. The spore on germination gives rise to hyphae, which branch repeatedly and become fused into a flat membrane, which develops into a more or less spherical disc. It differs from the vegetative thallus of the disc-forming *Trichopeltaceae* (e.g. *Brefeldiella*) only in the thicker hyphae which compose it, and in the presence of 2-celled hyphopodia, which can be traced on most of the branches forming the membrane.

In a recent collection from Buccleuch, Natal, an equally interesting fungus was found on the leaves and stems of *Piper capensis*. In this case the mycelium and spores are those of a typical *Meliola*, but the perithecium is of the *Microthyriaceae* type. The hyphae are thread-like, creeping over the leaf-surface, and bearing 2-celled capitate hyphopodia at regular intervals, and less frequently mucronate hyphopodia. The formation of the thyriothecium is similar to that of *Asterina*; a number of cells formed laterally on a hypha by repeated division (apparently by the septation of one of the hyphopodia) form a small group of parenchymatous cells between the mycelium and the leaf-surface, and these are the initial cells of the perithecial membrane. Each cell grows in a centrifugal direction, forming a series of radiating hyphae, which are fused by their lateral walls; thus a compact disc is formed, increase in circumference being provided for by the forking of the constituent hyphae. These hyphae are not fused for the whole of their length but are free at the circumference, giving the thyriothecium a fimbriate appearance. The thyriothecium differs from that of a typical *Asterina* only in the slightly stouter hyphae which form the membrane and in the presence of typical hyphopodia on the free ends of these hyphae. Dehiscence is stellate, as in *Asterina*, but the asci are 2-spored and evanescent as in *Meliola*, and the spores identical with those of the latter genus. This is interesting in view of Theissen's† statement that the hemispherical form of the fruiting body is evidently a development of the complete spherical form; that the thyriothecium of the *Microthyriaceae* has been reduced so that only the basal half has been formed, but this has been turned upside down and the perithecial wall is therefore "inverse."

There is no genus described with this type of perithecial membrane and 4-septate brown spores. I have therefore named this fungus *Meliolaster*, since it combines certain characters of the genera *Meliola* and *Asterina*.

Judging by the description given by Winter ('Hedwigia,' 1886, p. 96) and Gaillard ('Le Genre *Meliola*,' p. 58) it is possible that this fungus may

* Doidge, E. M., 'Trans. Roy. Soc. S.A.,' vol. v, pt. 6, pp. 727 and 744, pl. lxi, fig. 18

† See footnote, p. 121.

be identical with *Meliola asterinoides* Wint., in which case it should be named *Meliolaster asterinoides* (Wint.), but as I have not seen specimens of *M. asterinoides*, and it is not safe to assume the identity of the two fungi without comparison, I have described the Buccleuch specimen as *Meliolaster Mackenzii* n. sp.

MELIOLASTER Doidge nov. gen. MICROTHYRIACEARUM.

Thyriothecia superficialia, atra, carbonacea, appanato-hemisphaerica, ex hyphis radiatis contexta demum stellatum dehiscentia. Mycelium hyphopodium. Asci paraphysati. Sporidia 4-septata, brunnea.

Meliolaster Mackenzii Doidge n. sp.

Hypophylla, plagulas minutas, rotundatus, 1.5-2.5 mm. diam. formans; mycelio laxo, ex hyphis flexuosis vel fere rectis, 6-7 μ crassis composito; ramis alternis; cellulis 15-16 μ longis; hyphopodiis capitatis, alternis vel unilateralibus, brevissime stipitatis, curvatis, 10-15 \times 6-7 μ , cellula superiore sub-globosa, convexa; hyphopodiis mucronatis ampullaceis, inter hyphopodia capitata sparsis, apice interdum sub-uncinatis, 12-15 \times 6-7 μ ; thyriotheciis dense aggregatis, orbicularibus vel a latere compressis, appanato-hemisphaericis, 250-350 μ diam., contextu ex hyphis rectis, 4-6 μ latis in articulos circum 10 μ longos divisus composito, peripherice copiose fimbriatis; ascis paraphysatis, evanescentibus, ellipsoideis, bisporis, 50-57 \times 20-23 μ ; sporidiis cylindraceutis, compressis vel sub-clavatis, 4-septatis, utrinque rotundatis, leniter constrictis, 33-37 \times 10-13.5 μ .

Hab. in foliis *Piperis capensis*, 17/8/18, Buccleuch, Natal, leg. E. M. Doidge, M.H. No. 11570.

The formation of thyriothecia begins when the colony is quite small, the first being formed near the centre; one, two or more secondary thyriothecia then arise in close proximity, and these become flattened and the circular outline somewhat lost by coming into contact before growth is complete. As in *Meliola* the asci disappear as soon as the spores are formed, and before they change colour. The spores germinate as in *Meliola* and *Asterina* by producing hyphopodia first and then a hyphal branch, usually from the terminal cells. Hyphopodia are developed regularly as in many *Meliolas*, one being formed from each cell, in close proximity to the dividing wall.

SOME CONTROVERSIAL NOTES ON THE DIAMOND.

By J. R. SUTTON, M.A., Sc.D., F.R.S.S.A.,
HON. MEMB. R. MET. S., HON. MEMB. S.A.S.C.E.

(With one Text-figure.)

1. SPONTANEOUS BREAKING.

The 40th Article of Religion in Kimberley affirms that light brown smoky-looking diamonds always burst to pieces. So profound is the faith that a *débris* washer who finds such a diamond—which may have been out of the mine for forty years—will at once race off with it to a dealer, and will return triumphantly explaining how he “offloaded” it *before it burst*. In the same way a river digger who finds such another—which may have been tumbled in the gravels of the Vaal for ages—will carry it about in his mouth, or inside a potato, trembling until he has transferred the risk of its exploding to some buyer.

The thought that naturally arises upon reflection is that surely the dealers know all about the risk, and that the 40th Article is altogether in their own interests.

In recent times writers on the diamond, almost without exception taking the 40th Article for granted,* have suggested how the bursting might come about. G. F. Williams attributes it to dryness, or to heat, which may expand hypothetical contained gases when a diamond is taken from a mine; Crookes favours the idea of decrease of pressure in the space surrounding the diamond; Wagner goes the whole distance and claims that diamonds exhibiting the phenomenon of cracking or bursting are clearly in a state of great internal tension, like Rupert's drops.

Such explanations seem to be not specially applicable to brown or smoky diamonds; they would apply equally well to those of any other colour. Apart from that they are redundant for the reason that there is no indisputable evidence that diamonds: (1) burst; (2) contain gas in sufficient quantities to set up great internal strain under the small range of tempera-

* “ . . . sapiunt alieno ex ore petuntque
Res ex auditis ”—*Lucretius*.

ture to which they are exposed in the ordinary way of mining*; or (3) are in the condition of Rupert's drops.†

In other words, diamonds have not been known to burst, and, besides, there is no certain reason why they should do so. This was a principal argument in "Kimberley Diamonds: Especially Cleavage Diamonds" ('Trans. R.S.S.A.' 1918), and it is proposed to amplify it here, to answer some of the criticisms which have been launched against it, as well as to try to explain how the idea of bursting arose. Here the verb "to burst" is used in the ordinary sense as defined by the 'Oxford Dictionary': "To break suddenly, snap, crack, under violent pressure, strain or concussion. Chiefly said of things possessing considerable capacity for resistance, and breaking with a loud noise." That the verb has been understood in this sense, and not merely in that of a gentle breaking, disintegrating, pulverising, is evident since "to explode" is used as its equivalent,‡ and the behaviour of Rupert's drops has been invoked by way of illustration.

A friend writes me the following interesting remarks:

"I can form but little notion as to the extent to which your paper on Kimberley Diamonds may have reached the eyes of early diggers, of whom I was one as you know; but I am very sure that each one of such has been surprised at what you have written under the heading of 'Spontaneous Breaking.' To each this phenomenon is an established fact, and as such offering no possible ground for argument. The stones most liable to break up were sharp-edged octahedrons such as are most plentiful amongst the finds in the western portion of Kimberley Mine and (so far as I can recall) in Kimberley Mine only. In very many cases these stones had a more or less perceptible smoky cloud in one corner, and it became quickly known that such stones generally broke up spontaneously sooner or later. Various treatment was resorted to in the hope of saving, *e.g.* embedding in potato, wrapping in oil-rag or cotton-wool, and no doubt others of which I

* Cf. Sorby and Butler, "On the Structure of Rubies, Sapphires, Diamonds, etc."—Brewster "thought that the black specks, which were surrounded by a black cross when examined with polarised light, were minute cavities; but at the same time he admitted that they were so small that it was not possible to say whether they contained a fluid or were empty. Judging from what we have seen of such small examples, we consider it impossible to say whether they are cavities or enclosed crystals." 'Proc. R.S.', 1869.

† Some artificial diamonds may be likened to Rupert's drops—perhaps because they have been cooled too quickly. Crookes, in his magnificent Kimberley lecture, mentioned one which burst and covered with fragments the slide upon which it was mounted.

‡ *E.g.*—"It is notorious that the strain is occasionally so great that a diamond explodes into powder shortly after removal from its enveloping matrix of blue clay." A. E. H. Tutton, 'Crystals,' 1911, p. 207.

have no recollection if I ever had knowledge, but I cannot recall any case of success beyond securing a sale.

"A case: W. found a $2\frac{1}{2}$ carat, pure, sharp, glassy. T. saw and coveted the same to send to his wife, but funk'd a slight cloud in one corner. Eventually it was agreed that W. should hold the stone for three months, and if it were still sound T. would give £30 for it. The time passed, the stone was sound, and the sale was completed, and the proud T. put it with its pill-box full of cotton-wool in his pocket. Next morning I overtook T. on his road to work. His face was long, his brow was puckered. 'Look here,' quoth he, and produced the pill-box. 'This is the diamond I bought from W; on going to bed I put the box on my dressing-table; I awoke startled from my first sleep, lit a candle, opened the box, and look what I found.' I looked—cotton-wool and splinters! This case about mid-1872.

"Another case: I was buying diamonds in partnership with J. at this time. B. was in an office across the street. I happened to be alone when in came C. 'What will you give me for this?' 'This' proved to be a rather kidney-shaped smoky lump of 14 carats. 'What do you want?' 'Fancy stone! I want £10 a carat.' 'Give you bort price, 10s.' 'Rats' (if not more so). Talk. At last I offered 20s. as a spec.—it *might* not burst. 'That your best? Then I'll go to B.' Stone in hand he started across, I carelessly watching. He stopped suddenly, looked hard at his hand and turned back: 'All right old man, I'll take your offer; give the cheque.' 'Just let me look at the stone.' It was flawed through and through though still holding together. The above was as near to seeing the catastrophe as ever I went, and would have been near enough to convince me had I doubted. This about 1874."

It will be observed that the writer of the above letter considers that only Kimberley Mine diamonds were liable to burst, which limitation would still leave us without an explanation why there are broken diamonds (brown, yellow and colourless) in other mines. Also that W. held the suspected diamond without mishap for three months before T. bought it. Now when one asks believers in the 40th Article why diamonds do not burst in the De Beers sorting office, the answer commonly given is that they burst before-hand in the mine as soon as their matrix is disturbed—a quite reasonable argument if it had any tangible basis.

Another critic tells me that a diamond once broke (he does not say "burst") to fragments in his mouth, and that he had a very bad time before all the sharp pieces could be got out—which is scarcely consistent with the belief that diamonds kept in a wet place will not burst.

Heddle—writing from hearsay, of course, like the rest—about 1877, gives quite a different version of the story: "The cleavage of certain of the

African diamonds is so eminent that even the heat of the hand causes some of them to fall to pieces. Such diamonds, generally octahedra, may be recognised by a peculiar watery lustre: they are called plate diamonds."

2. OBSERVATIONS AND EXPERIMENTS.

Some of my own observations and experiments bearing on the question of broken diamonds may be of interest:

(1) A broken Koffyfontein diamond of good whiteness, of about four carats, and one-half the size of the original whole stone. There was a hole in the middle of the fractured face containing small pieces of foreign minerals, chiefly black. Held in a strong light under magnification a tiny crack, transverse to the fractured face, could be made out in the vicinity of the hole. A sharp jerk between thumb and finger broke the specimen through the crack as easily as a match can be broken. Some apophyllite had penetrated the crack. It is a fair inference that the original diamond crystallised, and broke, about some mineral inclusion. The half examined was in so precarious a state that merely dropping it on the table might have broken it. Anyone overlooking such a crack, as they easily might, and putting such a diamond away, say by tossing it in its paper envelope or pillbox into a safe, would find it broken the next day. And the incident would be quoted as another proof of the bursting of diamonds. Koffyfontein diamonds, it may be added, show more tendency to crack in two directions at right angles than do the diamonds from the Kimberley area—perhaps because of their prevailing irregular shape.

(2) Mr. Scott Ronaldson was good enough to show me a dull brown Kimberley Mine octahedron recovered from old *débris* which was seen to be slightly cracked when he bought it. Later it split in twain, showing then that it had crystallised about a smaller octahedron of somewhat similar colour and appearance, though of different orientation. Here again there is no need to invoke bursting. The case is just the same as those mentioned in my previous paper, namely, the unequal expansion and contraction of enclosure and inclusion.

In the De Beers collection there is a specimen resulting from the same process, half a diamond with an octahedron projecting from its broken face. The corresponding detached half has not been found. The projecting octahedron is remarkable in having rough edges like a Vaal River diamond.

In my own collection is a beautiful little colourless specimen in which a cup-like shell of diamond (one-half its original size) holds fast an octahedron. There is no indication of what filled the space between the inner and the outer diamond. There is a better specimen in the De Beers collection, a white octahedron penetrating the face of another, the second being attached to a cup-shaped shell like the previous one. Between the cup and the inclusion is a yellowish foreign matter containing black grains. Portions of diamond

shells are often found. The original whole shells evidently held inclusions nearly as large as themselves, then broke and the inclusions fell out. In some analogous cases inclusions have pushed holes through opposite faces of diamonds, leaving natural diamond beads.

Sometimes portions of such shells are found containing a material not unlike cement in appearance. I have a specimen whose dimensions are $6.5 \times 5.5 \times 2.5$ mm., the shell being no more than a millimetre thick. The specific gravity of the specimen is 3.56, indicating a denser material than diamond though softer—possibly diamond containing some impurity. Fragments of rounded specimens are occasionally found in which the cement and the transparent diamond are in alternate layers like the coats of an onion. Whatever the nature of this cement it sets up more strain than the thin diamond shells can resist.*

(3) Some experiments were made with a clouded brown Wesselton diamond of about three carats weight, much flawed and somewhat strained internally, with the object of increasing the strain or extending the cracks. These experiments consisted of heating the diamond in a test-tube in the flame of a spirit lamp, and of boiling it in water. The result was negative, and to all appearance the diamond is in the same condition now as it was before it was experimented upon many months ago.

(4) A nice rounded octahedron from Dutoitspan, of about three-quarters carat, in my collection, had a beautiful, slightly flawed smoky corner—just the sort of specimen to explode spontaneously according to the 40th Article. It was heated in the test-tube until the glass became soft, and was then placed under the receiver of a good air-pump and subjected to a considerable exhaustion of air. The flaw *may* have developed slightly under this drastic treatment.

3. DEDUCTIONS.

The generalisation here proposed is that owing to the small coefficient of expansion of diamond almost any inclusion will set up a state of strain in

* Sorby and Butler ('Proc. R.S.,' 1869) noticed that foreign inclusions exerted pressure on the surrounding diamond. And they say, "We, however, do not imagine that the crystals [inclusions] have increased in size, but that probably they have prevented the uniform contraction of the diamond, which must have been very irregular even when no such impediment was present." This suggestion ignores the contraction of the inclusion. There is something remarkably like hailstones in the structure of these specimens, and no doubt they have been formed like hailstones by alternate phases of crystallisation and accretion. Their characteristics must have an important bearing upon any rational theory of the genesis of the diamond. Could the old philosophers, who taught that precious stones were petrified ice, have seen such things they could have claimed a very decisive corroboration of their doctrine! "Other minerals, as fluor-spar, apatite, idocrase, heavy spar and calc-spar, disclose a similar structure by bands of different colours. A growth rendered intermittent through the deposition of a thin layer of foreign matter is thus developed" (A. F. Heddle, 'Ency. Brit.,' 9th ed., 1878, Art. 'Mineralogy').

a diamond sufficient at times to cause breakage under robust treatment. Many of the broken diamonds in the De Beers production may have fallen to pieces in the mining operations before they reached the sorting office. This is not an admission, of course, that they have been smashed by the machinery, for broken diamonds are found in the matrix: the hypothesis is that they are ready to break up, and that the mining operations, by shaking them up, help them to do so right out.

Fundamentally there is no difference between the spontaneous breaking of a pure colourless crystal diamond containing an inclusion and that of opaque or clouded diamond. In the former case there is a relatively large force concentrated at one place, and causing a definite split there; in the latter the distributed particles and finely divided colouring matter set up many small strains which, acting together, cause disruption of a similar sort to the pulverisation of the blue ground when this is exposed to the air.

The terms "bursting" and "exploding," therefore, must be regarded as



Bultfontein macle. $\times 5\frac{1}{2}$.

exaggerations of a simple tumbling to pieces. Opaque diamond will often break up quite easily. Wesselton black bort, when on the sorting tables, is mostly in fragments, or otherwise so much cracked as to be easily broken. From outside appearance there is more indication of bursting (as the term has been defined above) in a colourless diamond containing an inclusion than there is in any clouded stone. But no early digger has ever suggested the extension of the scope of the 40th Article so as to comprise the former.

4. PSEUDO-CLEAVAGE.

Some of the cleavages found in the Wesselton and Bultfontein mines appear at first sight to be fragments of broken diamonds. Closer inspection, however, shows that many have not the sort of freshly fractured surface that is got when a diamond is deliberately broken, but seem to have undergone some natural process of growth and solution subsequent to their disruption. And many, as said before, seem to have crystallised in a tight corner, where they had no chance to grow symmetrically. An inkling of what may sometimes take place is given by a Bultfontein diamond in my collection. This specimen is a clouded brown macle of the orthodox spinel

twin habit (a somewhat rare thing in the Kimberley mines),* measuring 6.7 mm. from corner to corner, and 5.5 mm. thick. To cursory inspection one of its triangular faces seems to be much cracked, but under moderate magnification the simulated cracks resolve themselves into deep natural grooves penetrating from a half to the whole way down to the seam (*i. e.* from a quarter to half way through the stone), the sides of these natural grooves not probably being in actual contact anywhere. On the face of the stone the sides of the grooves are striated like the edges of octahedra commonly are, or like the faces of rhombic dodecahedra from Bultfontein. It really seems as though the stone must have grown outwards from the seam in separate portions all at the same rate, keeping, that is, the overall dimensions to the correct spinel twin habit. The annexed picture is from a rough pen and ink sketch of the appearance of the stone. The thick lines indicate the grooves. This diamond evidently could be broken up into distorted fragments having pseudo-cleavage faces.

Sometimes two diamonds appear to have formed, one on either side of some foreign matter, the two together making one stone of passable shape. An interesting though not exceptional case is that of a Koffyfontein diamond of about two carats, one half of the diamond being white and the other half yellow with a tinge of brown. A light tap on the diamond with a metal weight, and it fell into two parts along the plane dividing the two colours. Inside there were two tiny zircons and some apophyllite. This was certainly not a case in which the diamond had formed normally about the zircons and split afterwards, for the crystallisation had proceeded by two separate intentions. Precisely similar cases of crystallisation on either side of flakes of diamond are met with.

5. GROUPS AND CLUSTERS.

Sir H. A. Miers observes ('Ency. Brit.', 1910) that "the majority of minerals are found most commonly in masses which can with difficulty be recognised as aggregates of crystalline grains, and occur comparatively seldom as distinct crystals; but the diamond is almost always found in single crystals, which show no signs of previous attachment to any matrix." The examination of many hundred specimens prompts me to suggest that his statement needs some modification. It may be granted that regular octahedra and other tesseral forms were almost certainly formed as single crystals; but the statistics given in "Kimberley Diamonds" show that these only make up a quarter of the whole production. Is it safe to dogmatise about the remaining three-quarters, even if there were no direct evidence? As it happens there is a good deal of direct evidence. Leaving out of account bort (which may be regarded as aggregates of crystalline grains), and interpenetrating crystals (found by the hundred at Bultfontein),

* Most Kimberley macles have rounded edges without re-entering corners.

and the terraced stones of Jagersfontein, groups and clusters of diamonds are by no means uncommon. These groups and clusters consist sometimes of diamonds of apparently perfect symmetry, sometimes of irregular lumps; and they may be all of one colour or there may be two or three different colours and textures. A brief description of one or two will suffice:

(1) A close cluster of separate diamonds, of which upwards of fifty can be counted on the outside. Originally it must have contained many more than it does now, for it is in so fragile a state that individual components are continually breaking away. Indeed, it is a wonder that it ever reached the sorting office as a cluster at all. The components are variously coloured from white to grey. Those that break off have fractured surfaces as well as surfaces of arrested growth.

(2) A crystal diamond surrounded by a cluster of lumps of bort.

(3) A branching group of five tiny dark grey diamonds, possibly coated stones. They seem to be rhombic dodecahedra, and are what is left of a larger group.

(4) A beautiful group of three tiny white diamonds, two of which are well-shaped octahedra and one rounded.

(5) An irregular group of ordinary grey bort of twenty or more components of irregular shape and of various shades of grey.

(6) A Bultfontein cluster of yellowish diamonds of different habits. The principal member is a macle of 8.7×5.1 mm., one of whose seamed sides has developed into an octahedral face. Another side and one corner are distorted where a satellite diamond has broken away; while a well-shaped macle, of the same thickness but smaller and not lying quite in the same plane, has grown into the third side. Close to the second macle is a distorted octahedron, one of whose corners shows where there was once another diamond. Wedged between the second macle and the distorted octahedron are two dodecahedra—there seem to have been three originally.

This list could be extended indefinitely; and considering that the chances are against a group or cluster surviving intact the ordeal of mining and winning it seems a fair inference that groups and clusters must be very common in the original matrix, and that it is immaterial to a diamond whether it forms individually or socially. In fact, saving lack of material, there is no reason why a group of diamonds should not extend from one side of the mine to the other.

It might be argued against this view that possibly the components of a group have started from closely situated independent centres of crystallisation and coalesced by natural growth. Without going so far as to assert that such a thing had not happened and could not happen, it may yet be said that chances and appearances are against any such phenomenon. Moreover the case of the Bultfontein spinel twin macle described and figured above, also the case following it of the Koffyfontein diamond, show in a way how

separate diamonds can grow outwards independently from a common starting-place. Then there are occasional diamonds which seem to have set out by first intentions to be cubes, but have developed incipient octahedral forms at each corner, thus assuming a distant resemblance to the rare form in which the octagon and the cube combine symmetrically—the corners of the octahedron projecting through the centres of the cubic faces. Equally significant are the octahedra with re-entering corners. Three of these have been preserved as good specimens—rounded octahedra of different sizes and colours. It was not easy to interpret the indented corners, but it seemed reasonable to suppose that they must once have contained octahedron diamond satellites. Later on another such diamond was found with the corner satellites *in situ* and strongly held.

Now these cases do seem to indicate a group-forming tendency. The corner satellites surely must have formed after the primary diamond had reached an advanced stage. For it is not in reason that seven distinct centres of crystallisation should start so symmetrically placed that six outer ones should be exactly at the places of the final corners of the central one. Still less is it in reason that the same process should be repeated again and again.

I would submit that a theory of growth into groups and clusters after the manner of calcite and rock crystal affords an explanation of the habit of many "cleavages," whose irregular contours are not bounded by broken surfaces. It explains, may we say, why so many diamonds appear to have been formed in tight corners, and why so many have what look like surfaces of attachment. The so-called cleavages found *in situ* in the matrix are more often such misshapen diamonds from clusters than fractured fragments derived from single crystals. A flat white diamond in its blue-ground matrix, from De Beers Mine, is one of these misshapen stones. Its exposed length is 10 mm.; its thickness varies from 1 to 3 mm. It projects 5 mm. from the blue ground, while its outside edge is broken off, accidentally or otherwise. It has all the appearance of having once been in a cluster, and its exposed faces are much the same as that which prevails when two diamonds have crystallised together in easy contact.

Bultfontein Mine produces more groups and clusters than other mines do, perhaps for the same reason that it produces more interpenetrating crystals than all the other mines put together. Cross-grained stones in general, however, are not uniformly distributed throughout Bultfontein, so that, consequently, some market assortments contain great numbers, whereas others have much fewer. This same mine is pre-eminently a source of rhombic dodecahedra, a good half of its symmetrical stones being of this habit; and the groups also seem to favour diamonds inclining to the same class.

6. RHOMBIC DODECAHEDRA.

Bultfontein rhombic dodecahedra merge on the one hand into occasional tetrahexahedra, white, yellow and green, and on the other hand by imperceptible gradations through rounded octahedra to some glassies. Those of the midway class are of special interest. For purposes of description they may be regarded either as octahedra whose edges have disappeared in solution, or as dodecahedra whose corners have been truncated by octahedral faces. The octahedral faces are usually much indented with triangles, the dodecahedral and tetrahexahedral faces never. When these two are indented at all it is with small round pits. It is curious that it is only in this midway class of Bultfontein diamonds that triakis—and hexakis—octahedral affinities are seen, namely when the dodecahedral or tetrahexahedral edges invade the faces of the octahedron. The typical Wesselton octahedron, for example, shows no such affinities.* The prevailing striated surfaces and rounded forms of Bultfontein diamonds create refraction troubles which make it difficult sometimes to see whether the interiors are flawed or spotted.

7. TWINS.

Interpenetrating twins are common enough at Bultfontein and relatively rare elsewhere. The two members of a twin combination are usually of the same habit, *i. e.* they may be both octahedra, or both dodecahedra, or both macles. But there is no hard and fast rule, and any possible form may occur twinned to any other. As to their origin, Crookes suggests that "two drops, joining after incipient crystallisation, might assume the not uncommon form of interpenetrating twin crystals." Some of these twins certainly look as if they might have been formed in some such way—say two octahedra or two dodecahedra joined point to point by the slightest of bonds, or a macle joined to almost any isometric. Yet outside appearances on the whole point to consecutive rather than to concurrent growth. For there is unbroken gradation all the way from simple contact between two complete crystals down to absolute inclusion of one by another. It would be quite easy to arrange a collection of Bultfontein twins showing progressively one of a pair more and more deeply embedded in the other, *i. e.* a point buried, a quarter buried, a half, three-quarters, and so on, then only a point sticking out, and lastly complete immersion.

It is not antecedently improbable, of course, that in each case the pair might have started together, and that one outgrew and in some cases finally, so to speak, overflowed the other. But it is just as likely that one might have started first, run its single course to the end, and then served as a nucleus for the other. And this view is supported by the venerable aspect of some inclusions.

* The green octahedra from the Rand basket show such affinities to perfection.

Again, on the hypothesis of concurrent growth, how can we explain the twinning when one member has octahedral characteristics (? indicating growth) and the other dodecahedral characteristics (? indicating resorption), both members being nearly of a size.

The mutual orientation of twins does not appear to be governed by any law: the axes of one member may be set at any angle to those of the others. There is a likelihood, however, that certain alignments may be favoured. Two macles, for example, interpenetrate by preference either nearly in the same plane though in opposite directions, or nearly at right angles, intermediate intersections being shunned. Even when the macles degenerate into bort they incline to the same rule. The McGregor Museum at Kimberley has a nice specimen of this interpenetrating maced bort.

Almost without exception there is great strain over the area where one of the twins cuts the other, whatever the depth of the union, due it may be to confused crystallisation about two sets of independent axes unsymmetrically co-ordinated.

8. HARDNESS OF THE DIAMOND.

Diamond is admittedly the hardest mineral in existence. But there is a good deal of misconception about the purport of the fact. Thus we are told (and can well believe) that there is a greater difference between the hardness of diamond (10) and that of corundum (9) than there is between the hardness of corundum and that of talc (1); and thence we are asked to infer that nothing else on earth will scratch diamond. Herbert Smith, for example, says that Borneo diamonds "are remarkable for excessive hardness; they can only be cut with their own dust, ordinary diamond dust making no impression" ('*Gem Stones*,' p. 154, 1912). Miers says that because of their hardness diamonds obtained from sands or gravels are rarely, if ever water-worn ('*Ency. Brit.*,' 11 Ed., 1910).

Now in order to be quite emphatic we will begin with the round assertion that there is nothing on earth that will *not* scratch a diamond. Drops of water wear away the stone. Every mineral will scratch every other. It is only a question of time and quantity of material. Given time enough a wheel of gypsum, if large enough, would grind a diamond to powder. The point of a glazier's diamond wears out in time; and so does carbonado used in a rock drill. Some years ago a large diamond was used in the De Beers workshops to take half an inch from the circumference of a corundum wheel fourteen inches in diameter. It did the work, but suffered grievous wear in the process.

Thus the water-worn aspect of innumerable diamonds obtained from gravels is no matter for wonderment. I have seen a Vaal River diamond worn as round and as rough as a marble, with scarce a trace of its original

surface left.* More than that, a large yellow diamond belonging to the estate of the late Mr. B. Peiser a few years ago was scored with "criss-cross" glacial striæ. Hence the argument that a diamond could not have been used in the breastplate of the High Priest (Exodus XXVIII, 18) because the Hebrews knew of no means of engraving a sign upon it loses some of its force.† Besides, it is only surmised and has not been proved that no lapidary of old had ever found out how to engrave a diamond. Arts are acquired and perish: *e. g.* the way to cleave diamond was learned and forgotten before Wollaston's time.

Note.—Speaking of things that are hard Lucretius says that:

"In quo iam genere in primis adamantina saxa
Prima acie constant ictus contemnere sueta."

H. A. J. Munro gives "diamond stones" as the equivalent of "adamantina saxa." But *cf.* 'Ovid,' *Fasti* III:

"Immolat hunc Briareus facta ex adamante securi,"

which certainly cannot be a diamond axe. F. A. Paley suggests basalt.

* (1) "The diamond, in spite of its great hardness, is readily affected by attrition when transported over even relatively short distances."—H. Merensky, "The Origin of River Diamonds within the Area of the Vaal," *Trans. Geol. Soc. S.A.*, 1907. (2) "The distinct wear seen on many of the river diamonds suggested the same source (the Dwyka) for many of those gems, as the attrition due to a slow-moving ground moraine, especially at or near its base, would be great enough to wear and triturate even the diamond."—H. S. Harger, "The Occurrence of Diamonds in Dwyka Conglomerate, etc.," *ibid.*, 1909.

† Apart from that a diamond in the breastplate might have had a natural mark upon one of its faces which simulated the signet sign of one of the tribes. Diamonds occasionally carry remarkable intaglio outlines suggestive of the art of a runic scribe. On the other hand, the Septuagint (Lee Brenton's Version) does not use the word diamond (ὁ ἀδάμας) at all, but supplies some variant in every case, *e. g.*, ἰασπις in Ex. xxviii, 18, σμάραγδος in Ez. xxviii, 13, and curiously, χαπαύρις in Ez. iii, 9.

SOUTH AFRICAN PERISPORIACEAE.

By ETHEL M. DOIDGE.

(With Plates VII and VIII.)

V. NOTES ON AN INTERESTING COLLECTION FROM NATAL.

During July of this year an interesting collection of leaf fungi was made at three localities in Natal. The largest number of specimens was obtained at Buccleuch, near Cramond, on the 16th and 17th; smaller collections were made at Zwartkop on the 19th and at Hilton Road on the 21st of that month. A large proportion of the fungi belong to the genus *Meliola*, and include a number of undescribed species, some of which have been collected on previous occasions in an immature condition, or so overgrown with parasites as to make a careful study impossible. A number of species previously recorded have also been collected on different hosts.

Meliola amphitricha, Fr.

On *Olea laurifolia* Buccleuch (11557).

On *Plectronia guenzii* Buccleuch (1576).

This species was collected on *Olea laurifolia* in the Woodbush and occurs on a variety of hosts belonging to the *Rubiaceae*, *Oleaceae*, and *Sapindaceae*. It has not been previously recorded on a *Plectronia*, the species most commonly found on this host being *Meliola falcata* Syd.

Meliola (Fig. 1).

On leaves of an unknown shrub, probably belonging to the *Myrtaceae*, Zwartkop (11594). This fungus is chiefly epiphyllous and forms small, sooty black, crustaceous growths which are easily separated from the leaf surface. The leaf tissues covered by the mycelium are brown and discoloured.

Meliola atra n. sp.

Amphigena, plerumque epiphylla, maculas atras, crustaceas, 3-4 μ diam. efficiens; hyphis fuscis, 7-10 μ crassis, cellulis brevis, 12-16 μ long., interdum ad septa constrictis; ramis plerumque oppositis; hyphopodiis capitatis alternis vel unilateralibus, breviter stipitatis, 20-27 \times 16-20 μ , cellula superiore magna, inaequaliter lobulata; hyphopodiis mucronatis non numerosis, oppositis v. unilateralibus, pyriformibus v. sub-conicis, 10-13

$\times 6-7 \mu$. Peritheciis non numerosis, atris, carbonaceis, 200μ diam. (non maturis); ascis non visis; sporidiis late ellipsoideis, 4-septatis, vix constrictis, utrinque rotundatis, $50-54 \times 20-24 \mu$.

In foliis fruticis ignotis, Zwartkop, 19/7/18, leg. Doidge (M. H. No. 11594).

Meliola Cryptocaryae Doidge.

On *Cryptocarya Woodii* Zwartkop (11603.)

Meliola sp. (Fig. 2).

On the same leaves as *Meliola atra*. There is also on these leaves a fungus belonging to the *Trichopeltaceae* and one belonging to the *Hemiasphaeriaceae*, both immature, and a species of *Asterina*. The general habit of the *Meliola* is very similar to that of *Meliola Helleri* Earle, which occurs in Porto Rico, but the setae are not forked as called for in the description of *M. Helleri* and the spores and hyphopodia differ somewhat in size.

Meliola cylindripoda n. sp.

Amphigena, plerumque hypophylla, pelliculas tenues subindefinitas, nigras, $3-6 \mu$ diam., formans, saepe plus minusve confluentis; mycelio intertexta, pallide fusco; hyphis $6-7 \mu$ crassis, irregulariter undulatis, cellulis $20-27 \mu$ long., ramis oppositis; hyphopodiis capitatis alternis v. unilateralibus, breviter stipitatis, $12-16 \times 6-9 \mu$; cellula superiore cylindracea; hyphopodiis mucronatis paucis, oppositis v. sparsis, ampullaceis v. pyriformibus, $16 \times 6-7 \mu$; setis mycelicis parvis, simplicibus, rectis v. flexuosis, $300-500 \mu$ long., basi $6-7 \mu$ crassis, opacis, ad apicem pallidiorem paulatim attenuatis; peritheciis sparsis, globosis, minute verrucosis, $200-240 \mu$ diam.; ascis evanidis; sporidiis $40-44 \times 15-17 \mu$, cylindraceis, atro-fuscis, utrinque rotundatis 4-septatis, leniter constrictis.

In foliis fruticis ignotis, Zwartkop, 19/7/18, leg. Doidge (M. H. 11596).

Meliola ditricha K. & Cke. (Doidge).

On *Olea laurifolia* Bucoleuch (11615) and on *Gymnosporia* sp. Bucoleuch (11572). This species was described from material collected by Medley Wood in 1876 ('Trans. Roy. Soc. S.A.,' vol. v, pt. 6, p. 728) on *Celastrus* sp. on which the perithecia were immature. Recent collections show abundant mature perithecia, they are $280-320 \mu$ diam. and have conical chitinous appendages about $30-40 \mu$ long; these are more opaque than is usual in these perithecial appendages. The form on *Olea* is more effuse and the hyphopodia somewhat larger ($33-40 \times 13-10 \mu$) than that on *Celastrus*. On *Olea* the fungus is usually heavily parasitised and does not often form perithecia. *Meliola ditricha* has also been collected on *Olea laurifolia* at Tabankulu, Transkei, 15/3/15, by G. Fraser (M. H. 8888), and on *Pleurostyliia capensis*, van Stadens Pass, 13/11/17, leg. E. M. Doidge (10883).

Meliola sp. (Fig. 3).

On *Ezcoecaria caffra*, Buccleuch; forms very conspicuous olive green spots, but is usually very heavily parasitised, and seldom forms perithecia. It does not agree with the description of any other species in the group with 4-septate spores and simple mycelial setae.

Meliola Ezcoecariae n. sp.

Amphigena, maculas rotundatas v. irregulares, 5-10 μ diam. formans; hyphis fuscis, undulatis, 6-8 μ crassis; ramis plerumque alternis; hyphopodiis capitatis alternis, stipitatis, 23-35 \times 10-16 μ , cellula basali 7-10 μ long., cellula superiore varie lobata, plerumque obtuse tri-lobulata v. triangulata; hyphopodiis mucronatis oppositis v. sparsis, ampullaceis v. piriformibus, 15-20 \times 6-7 μ ; setis mycelicis parvis, 300-500 μ opacis, basi 6-7 μ crassis, haud attenuatis sed apice abrupte acuminatis; peritheciis atris, globosis, carbonaceis, 145-170 μ diam. (maturis?) asci evanidis, sporidiis 4-septatis cylindraceis, utrinque rotundatis, vix constrictis, 35-40 \times 13-17 μ .

In foliis *Ezcoecariae caffrae* Buccleuch, 17/7/18, leg. Doidge (11566), Buccleuch, 23/3/16, leg. Doidge (9705).

Meliola furcillata Doidge.

This species was described ('Trans. Roy. Soc. S.A.,' vol. v, pt. 6) as occurring on the leaves of *Maesa rufescens*; later collections have been made, all on leaves of *Schmidelia monophylla*, and a careful re-examination of the original material shows that this was incorrectly determined, and that all collections of this fungus are on the same host. *Meliola furcillata* has been collected on *Schmidelia monophylla* at Amanzimtoti (Type M. H. 1573), Winterskloof, Claridge, 31/5/15 (8993) and at Buccleuch (11577).

Meliola ganglifera Kalch.

On leaves of *Curtisea faginea*, Zwartkop (11601). This fungus forms very conspicuous black spots on the leaves of *Curtisea faginea* and occurs very commonly on this plant in Natal, the Transvaal and the Cape Province.

Meliola sp. (Fig. 4).

On *Celastrus cordatus*? is a very showy species with 3-septate spores; the colonies show fairly distinct concentric zones. This species is remarkable for the very numerous larviform appendages on the perithecia; apparently almost all the superficial cells develop into appendages. The group with 3-septate spores, which is a comparatively small one, is very well represented in South Africa.

Meliola gloriosa n. sp.

Hypophylla, ferruginea, maculas orbiculares 5-10 μ diam. formans;

mycelio radiato; hyphis tenuibus, 4-5 μ crassis, tortuosis, dense intertextis, cellulis 30-50 μ longis; ramis alternis, hyphopodiis capitatis alternis, tenuibus, stipitatis, 30-80 \times 13-20 μ , stipite interdum elongato et 1-septato, 14-64 μ long., diverse flexuoso v. curvato, cellula superiore 16 μ fere longa; irregulare, plerumque sub-lobata, nonnunquam inverse triangulata; hyphopodiis mucronatis parvis, pallidioribus, tenuibus, 18-20 \times 5-6 μ ampullaceis v. gibbosis; setis nullis; peritheciis numerosis, globosis, atris, carbonaceis, 300-400 μ diam., appendiculis numerosis, larviformibus, subcylindraceis v. acclivis, 65-80 \times 25-30 μ apice interdum recurvatis; asci evanidis; sporidiis 3-septatis, ellipsoideis, vix constrictis, 45-50 \times 15-16.5 μ .

In foliis *Celastrus cordatus*? Buccleuch, Natal, 17/7/18, leg. Doidge (11565).

Meliola Hendeloti Gaill.

On *Clerodendron* sp. Buccleuch (11571).

Meliola inermis Kalk & Cke.

On *Buddleia pulchella* Buccleuch (11568).

On *Chilianthus dysophyllus* Buccleuch (11583).

This species has only been recorded in South Africa on *Buddleia* spp.

Meliola malacotricha Speg.

On *Indigofera cylindrica* Buccleuch (11560).

Meliola microspora Pat. & Gaill. var. *Africana* on *Plectranthus* sp. Buccleuch (11576).

Meliola natalensis Doidge.

This species was described ('Trans. Roy. Soc. S.A.' vol. v, pt. 6, p. 724) on leaves of shrub unknown, Umgeni, near Durban (8980); on comparison with named specimens this host appears to be *Dovyalis tristis*, and the same species has been collected by Dr. Pole Evans on *Dovyalis rhamnoides* (Umgeni Beach, Durban, 4/6/12 [2312]).

The original specimen of *Meliola conferta* Doidge (*ibid.*, p. 724) is also on *Dovyalis rhamnoides*, and consists of some rather old material collected by Dr. Medley Wood; more recent collections on this host show that the spores in the type collection have collapsed somewhat and appear wider than normal, so that the normal measurement of the spores is 40-45 \times 14-16.5 μ , rarely larger. This being the case *M. conferta* only differs from *M. natalensis* in the more crowded habit and the slightly smaller hyphopodia.

In a recent collection at Buccleuch on *Dovyalis tristis* there is a form which agrees with *M. natalensis* in the form of its hyphopodia and spores, but with quite a different habit (Fig. 5) from either *M. natalensis* or *M. conferta*; the mycelium is very diffuse, not forming definite spots, and the hyphopodia are very remote. I can only conclude that these are all forms

of a very variable fungus, and should be regarded as varieties of *M. natalensis*. The collections in the Mycological herbarium would then be classified as follows:

Meliola natalensis Doidge.

On *Dovyalis tristis* (type), Umgeni Beach, 27/5/15, Doidge (8880).

On *Dovyalis rhamnoides*, Umgeni Beach, 7/6/12, Pole Evans (2412).

Var. *conferta*; differs from the type in the crowded and usually opposite hyphopodia, which are slightly smaller than those of the type.

On *Dovyalis rhamnoides*, Durban, Medley Wood (345), (Wood, 6457). (Wood, 6454).

Var. *laxa*. Spores slightly smaller than type (seldom exceeding $40 \times 14 \mu$), hyphopodia remote; on leaves of *Dovyalis tristis*, Hilton Road, 21/7/18, E. M. Doidge (11608).

Meliola sp. (Fig. 6).

On leaves of *Ochna atropurpurea* var. *natalitia*; this is one of the large group with 4-septate spores and simple setae; it does not agree exactly with any species previously described.

Meliola Ochnae Doidge n. sp.

Amphigena, maculas irregulares $4-8 \mu$ diam. efficiens; hyphis fuscis, undulatis, $5-6 \mu$ crassis; ramis oppositis, anastomosantibus; cellulis plerumque $20-25 \mu$ long.; hyphopodiis capitatis alternis, raro oppositis, breviter stipitatis, $12-16 \times 6-7 \mu$, cellula superiore oblonga v. ovata, saepe curva; hyphopodiis mucronatis oppositis vel sparsis, ampullaceis, $15-20 \times 6 \mu$; setis myceliis non numerosis, circa perithecia praecipue evolutis, simplicibus, rectis v. flexuosis, saepe subrennatis, acutis, $240-350 \mu$ long., basi $6-7 \mu$ crassis, ad apicem paulatim attenuatis; peritheciis parvis, sparsis, atris globosis, carbonaceis, verrucosis, $145-175 \mu$ diam.; ascis evanidis; sporidiis 4-septatis, brunneis, ellipsoideis, utrinque rotundatis, leniter constrictis, $35-37 \times 12-14 \mu$.

In foliis *Ochnae atropurpureae* var. *natalitiae* Buccleuch, Natal, 17/7/18, leg. Doidge (11567), Winter's Kloof, 1/6/15, leg. Doidge (8989).

Meliola peltata Doidge.

On *Podocarpus falcata* Buccleuch (11551); has previously been collected only on *Podocarpus latifolia* in the Cape Forests (Knysna and George).

Meliola sp. (Fig. 7).

On *Olea laurifolia*; on the same leaves as *Meliola amphitricha* and *M. ditricha* there is a third species of *Meliola* which clothes the petioles and also forms elongated colonies under the margin of the leaf; on the petioles it forms a dense black mat which readily separates from the substratum;

on the petioles also, both mycelial setae and perithecia are formed in great abundance, and they are much less numerous in the spreading colonies along the leaf margin. It belongs to the comparatively small group with definitely uncinat mycelial setae.

Meliola petiolaris Doidge n. sp.

Hypophylla et petiolicola, velutina, atra, peritheciis intra setas myceliales numerosissimas absconditis, globosis, atris, minute verrucosis, 220–250 μ diam.; mycelio ex hyphis fuscis anastomosantibus 5–6 μ crassis composito; cellulis 25–30 μ long.; ramis oppositis; hyphopodiis capitatis alternantibus, tenuibus, 15–40 μ long. \times 10–13 μ crassis, cellula basali saepe 1-septata, cellula superiore obovata, truncata v. sub-lobata, hyphopodiis mucronatis non visis; setis mycelicis simplicibus, curvatis plerumque uncinatis, 150–250 μ long., basi 8–9 μ crassis, ad apicem obtusum leniter attenuatis; ascis 2–3 sporis, evanescentibus; sporidiis cylindraceis utrinque rotundatis as septa leniter constrictis, 40–44 \times 13–16 μ , loculo medio saepe longiore.

In foliis et petiolis *Oleae laurifoliae* Buccleuch, Natal, 17/7/18, leg. E. M. Doidge (11558).

Meliola Podocarpi Doidge.

Associated with *M. peltata* on the leaves of *Podocarpus falcata* Buccleuch (11552), also on *P. elongata* (11561).

Meliola sp. (Fig. 8).

A rather inconspicuous species on *Popowia caffra* which has been collected several times in an immature condition. It has previously been found at Kentani (A. Pegler, 1996) (8882) and Winter's Kloof (8990).

Meliola Popowiae Doidge n. sp.

Epiphylla, effusa, pelliculas tenues nigras formans, hyphis brunneis, inaequalibus, undulatis, 6–7 μ crassis; cellulis, aliis 30 μ aliis 10 μ longis; ramis oppositis v. irregularibus; hyphopodiis capitatis stipitatis plerumque ad pares angulos hyphibus, 12–15 \times 8–10 μ , cellula superiore globosa; hyphopodiis mucronatis sparsis v. oppositis ampullaceis, rectis v. curvis, 16 \times 6 μ ; setis mycelicis parvis, circa perithecia praecipue evolutis, simplicibus, flexuosis, 300–500 μ long., basi 10 μ crassis, nonnihil ad apicem (6–7 μ cr.) attenuatis. Peritheciis paucis, globosis, atris, carbonaceis, verrucosis 180–200 μ diam., ascis evanidis; sporidiis 4-septatis, cylindraceis, ad septa constrictis, utrinque rotundatis, 35–40 \times 13–16 μ .

In foliis *Popowiae caffrae* Buccleuch, Natal, 17/7/18, leg. Doidge (11587); Hilton Road, 21/7/18, leg. Doidge (11607).

Meliola Rhois P. Henn.

On *Rhus laevigata*, Buccleuch (11582); on *Rhus* sp., Buccleuch (11595).

Meliola rigida Doidge.

On *Xymalos monospora*, Buccleuch (11578).

Meliola Toddaliae Doidge.

On *Toddalia lanceolata*, Buccleuch (11564).

Meliola varia Doidge.

On *Rhoicissus rhomboidea* Buccleuch, 20/7/18, J. Leighton (11554). This is a comparatively rare species, and was not plentiful on the host even after the exceptionally heavy rains which fell last season.

EXPLANATION OF PLATES VII AND VIII.

[All drawings were made with the camera lucida, Zeiss objective D. and a No. 5 ocular.]

PLATE VII.

FIG.

1. *Meliola atra*. (A) Mycelium with capitate hyphopodia; (B) spores.
2. *Meliola cylindripoda*. (A) Mycelium with capitate hyphopodia; (B) hypha with mucronate hyphopodia; (C) spores; (D) tips of setae.
3. *Meliola Ezcoecariae*. (A) Mycelium with capitate hyphopodia; (B) hypha bearing mucronate hyphopodia; (C) tips of setae; (D) spores.
4. *Meliola gloriosa*. (A) Mycelium with capitate hyphopodia; (B) mucronate hyphopodia; (C) spores; (D) perithecial appendages.

PLATE VIII.

5. *Meliola natalensis* var. *laxa*. (A) Mycelium with capitate and mucronate hyphopodia; (B) perithecial appendages; (C) spores.
6. *Meliola Ochnae*. (A) Mycelium with capitate hyphopodia; (B) hypha with both kinds of hyphopodia; (C) tips of setae; (D) spores.
7. *Meliola petiolaris*. (A) Mycelium with capitate hyphopodia; (B) tips of setae; (C) spores.
8. *Meliola Popowiae*. Hyphae with (A) capitate hyphopodia and (B) mucronate hyphopodia; (C) tips of setae; (D) spores.

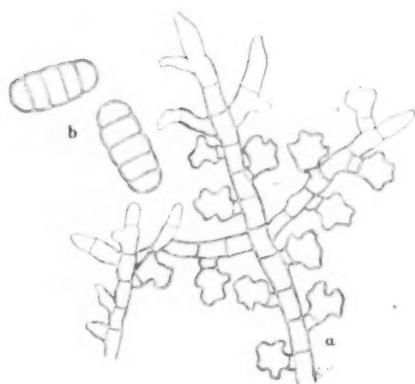


FIG. 1.

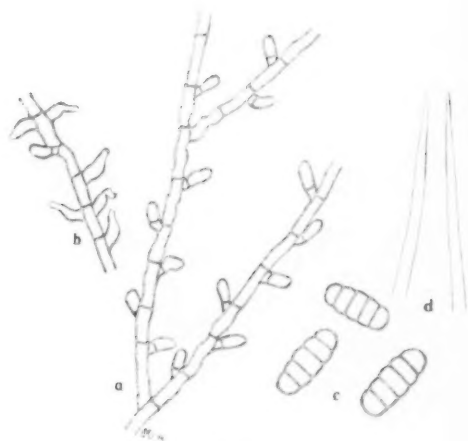


FIG. 2.

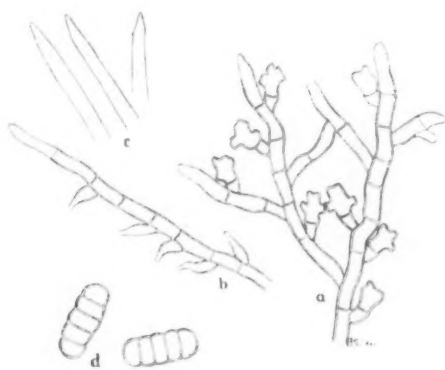


FIG. 3.

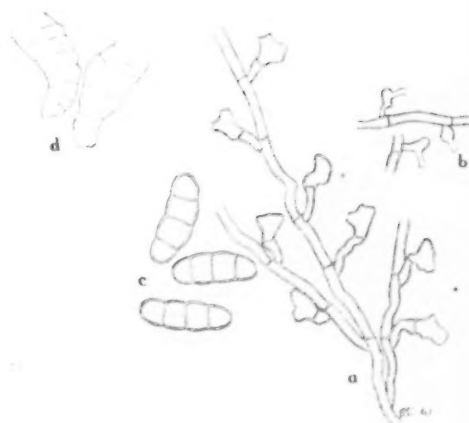


FIG. 4.

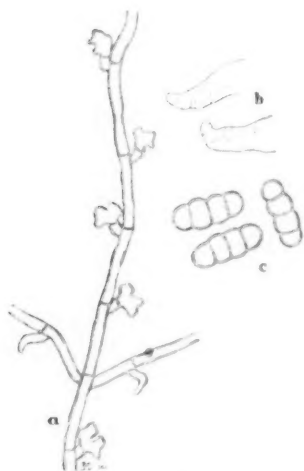


FIG. 5.

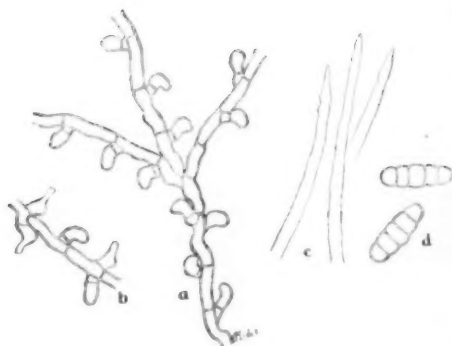


FIG. 6.

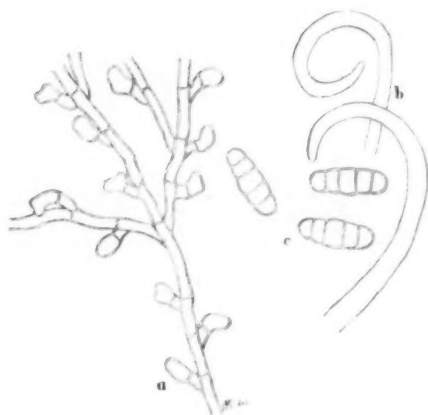


FIG. 7.

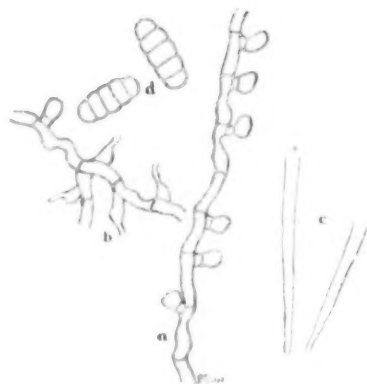


FIG. 8.

NOTE ON THE SHELLS OF *SCHIZODESMA SPENGLERI* LINN.

By J. D. F. GILCHRIST, M.A., D.Sc., Ph.D.

The sands of Muizenberg, though at times so apparently barren and devoid of animal life, prove on closer acquaintance to present many features of interest for zoological study. Frequently after a strong "south-easter" there are cast up many diverse forms of pelagic life. Millions of *Physalias*, the "Portugese Man of War" or "Blue Bottle" as they are called locally, may form a blue band at high-water mark extending for miles along the shore. Among them are other pelagic forms—*Porpita*, *Verella*, *Ianthina*, etc. Over the wet sand may be seen hurrying about the little active mollusc, *Bulla digitalis*, and under it are multitudes of "White Mussel," *Donax serra*, and many burrowing prawns, whose presence is only indicated by the openings of their burrows at the surface. After a north-west wind other forms appear, brought up by the under-current, such as masses of "red bait" and various kinds of shells, prominent amongst which is a large bivalve (*Schizodesma spengleri*).

It is, however, not only the zone between the tide-marks that is of interest, but also the zone above high-water mark, for here the fine sand has been carried back by the wind to form the long line of high sand-dunes, and the heavier shells have been left exposed in profusion.

It is to a peculiarity amongst these that I wish to direct attention. They consist of a variety of different kinds and from various sources. The delicate blue shells of the pelagic *Ianthina* are sometimes found intact, as well as the thin shell of the "toe loeppel," or "teaspoon shell" (*Lima hians*). The stouter shells of other bivalves, such as *Venus verrucosa*, *Dossinia ecoleta*, *Donax serra*, *Lutraria oblonga* and *Macra glabrata* are to be found in abundance, but the commonest is the large bivalve *Schizodesma spengleri*, readily recognised by its large thick valves, with a strong ridge along its outer surface. It is known to fishermen as the "Doed-Mossel." It is a sub-genus of *Macra* and is peculiar to the Cape of Good Hope.

This shell is the largest and one of the stoutest of the shells, and yet, as may be readily noted, it is the one of which most broken fragments are to be seen. Moreover, these fragments are not like those of other shells as a rule, for the fracture appears to be sharper and unweathered. Again, it may be

observed that the fracture is not at the weakest part, the thin edge of the shell, but often passes through the thick part, at or near the hinge where the shell is about 3 mm. in thickness. A further point that is to be noted is that, while many of these shells are broken up into half a dozen or more pieces, others are entirely uninjured.

An obvious and apparently sufficient explanation of this is that the shells have been accidentally crushed by men or animals walking along the sand. The same peculiarity, however, was found in unfrequented parts of the beach, and, moreover, it was found by experiment that the shells are so strong that, on treading on them heavily, they are simply pressed into the underlying sand. Again, other bivalve shells of a more fragile structure were not so damaged. Further, it was observed that fresh shells just cast up by the waves showed the same feature. These were still attached in pairs by the ligamentous hinge and contained the fresh tissue of the animal, or as much of it as had been left by the sea-birds, which readily devour the exposed body of the animal. There were two conditions observed in these shells. Either the two valves were intact, or one was intact, the other being broken into several small pieces. Seldom were both shells broken.

The local name "Doed-Mossel" is probably due to the fact that, though the dead shells are found in abundance, the living animal is not often seen. Sometimes, however, the entire shells and the contained living animal are to be found. The shells are almost as firmly held together as in the living oyster, and cannot be opened without some instrument to rupture or cut the adductor muscles, and yet, in some way, the sea-bird (*Larus dominicanus*) is enabled to get at the animal soon after it is cast up by the waves.

On one occasion a group of these birds was observed on the beach, feeding on the mollusc, and it was obvious that the shells had just been opened, the remaining part of the tissue of the animal being quite fresh. In some cases the two valves were uninjured, and in others one valve only was injured, having been broken in several pieces, which were found close by. On being disturbed the birds made off, but soon after returned. Observed from a distance, they were seen to pick up the shells in their beaks and let them drop on the wet sand from a height of about 20 or 30 feet. It is well known that some birds have the habit of breaking open the hard shells of their prey by such a device, and it was at once surmised that this was the method of procedure in this case, though the shells were broken on one side only, and then often through the thickest part of the shell. Moreover, this apparently did not explain the opening of the shell without any breaking. It was a simple matter, however, to put this to the test. An unopened shell containing the living animal was obtained and was thrown into the air to a height of 20 or 30 feet. It fell on the sharp closed edges of the shell and was quite uninjured. On a repetition of the experiment, however, the shell fell on its side, and this had the effect of breaking

the lower shell into about half a dozen pieces, while the upper shell remained intact. These experiments were repeated, and in one the animal fell on the hinge of the shells, the unexpected result being that the two shells opened widely and remained so as if the animal had been paralysed by the shock.

This, therefore, appears to be sufficient explanation of the condition of the shells so characteristic of those found above high-water mark.

AN EXTREME CASE OF MICROCEPHALY.

By E. G. DRU-DRURY, M.D., B.S., D.P.H.

(With Plates IX and X.)

There is a skull preserved in the Port Alfred Mental Hospital, which excites the cupidity of all instructed beholders.

It belonged to a Basuto woman, who died in the institution from tuberculosis at the age of 32.

She was in all other respects well formed physically, of the size of a child of 12, and weighed 60 lbs.

M. J. is described as restless, full of twitching movements, turning her head and eyes rapidly, dirty in her habits, but able to feed herself.

In temper she was impulsive, "biting, kicking, and scratching." "When frightened, or annoyed by the other patient, she flies to an officer, clinging to his legs, and crouching down. Behind this protecting shelter she grimaces and makes noises at her enemy, as if in defiance of anything he can do."

After two years of institutional life she learned to do some work in the laundry, and became cleanly, "exhibiting a wonderful amount of intelligence for the apparent size of her brain."

Two years later she is described as "very fond of music and dances when she hears it."

"During life she was able to make use of a limited number of words and was very affectionate to those who treated her kindly."

The earliest words were Basuto and incoherent, the later are said to have been "mostly swear words," and therefore presumably English. Unfortunately no record of her actual words exists.

After another two years she died.

The above description is drawn from the case books at Grahamstown and Port Alfred, and particularly from notes by Dr. W. G. Atherstone. Her appearance at a medical meeting in 1904 was certainly ape-like, as all observers agreed.

Through the courtesy of the Medical Superintendent, Dr. Walter Atherstone, I was enabled to make an examination of the skull.

Mr. John Hewitt, Director of the Albany Museum, very kindly took four excellent photographs of the skull, and I am much indebted to him for the pains that he expended.

FEATURES OF THE SKULL.

Norma Verticalis Phaenozygous.

The whole of the frontal bone, from glabella to bregma, is visible. The glabella is prominent, forming, with the upper orbital margins, a bracket-shaped curve.

In this view one also sees the whole of the zygoma, the whole lower margin of the orbit, the alveolar border of the upper jaw as far back as the first premolars; both mastoid processes are visible. The temporal fossae are deeply indented. (In the photo the slight tilting of the specimen and the monocular vision of the camera yield slightly different results.)

Norma lateralis.

This shows well the extreme prognathism; all the teeth are perfect, but the lower central incisors show some absorption of alveolus.

Norma facialis.

Very little of the cranium is visible.

Norma occipitalis.

The supra-occipital portion of the occipital bone is very small. Below the inion the bone makes an acute angle with the horizon.

Norma basalis.

The insignificance of the cranium is a marked feature. The mental tubercles are almost absent, being just perceptible to touch.

Principal Measurements.

| | |
|---|---------|
| Length of skull | 123 mm. |
| Breadth of skull | 86 " |
| Height above external auditory meatus | 77 " |

This gives a cranial index of 69.9, or a marked degree of dolichocephaly, yet one which is exceeded by present-day Hottentots and Australian bushmen; and an altitudinal index of 69.9 mm. (tapeinocephaly).

Cranial capacity 340 c.c., i. e. equal to an infant of two weeks old. The capacity was repeatedly measured with Kafir corn seeds, well shaken down without ramming, and actually gives a reading less than some anthropoid apes.

| | |
|----------------------|-----------|
| Gorilla | 557 c.cm. |
| Chimpanzee | 427 " |
| M. J. | 340 " |
| Baboon | 210 " |

A list of more detailed measurements is appended.

Transverse Measurements.

| | |
|---|--------|
| Bi-frontal distance (processus zygomaticus) | 81 mm. |
| Bi-zygomatic distance | 96 " |
| Bi-stephanic distance | 66 " |
| Bi-parietal distance | 86 " |
| Bi-mastoid distance | 92 " |
| Bi-asterial distance | 76 " |

Longitudinal Measurements.

| | |
|---------------------------------------|---------|
| Glabella to occipital point | 123 mm. |
| Nasion to basion | 77 " |
| Basion to opisthion | 28 " |
| Basion to alveolar point | 84 " |

Vertical Measurements.

| | |
|----------------------------------|--------|
| Bregma to basion | 86 mm. |
| Nasion to mental point | 97 " |

Girths.

| | |
|---|---------|
| Circumference, glabella to opisthion | 333 mm. |
| Vertical girth (bregma and auricular point) | 300 " |
| Longitudinal arc (nasion to opisthion) | 218 " |
| Frontal portion of arc | 78 " |
| Parietal portion of arc | 68 " |
| Occipital portion of arc | 72 " |

Special Measurements.

| | |
|---|--------|
| Orbit: Height | 33 mm. |
| Breadth | 32 " |
| Index | 103.1. |
| The orbit is megaseme to an extreme degree. | |
| Nose: Height | 40 mm. |
| Breadth | 23 " |
| Index | 52.5. |

The nose is thus mesorhine.

Other Indices.

| | |
|-----------------------------------|--------|
| Dental index of flower: | |
| Length | 38 mm. |
| Basi-nasal length | 77 " |
| Index (mesodont) | 43.35. |
| Palato-maxillary index of flower: | |
| Length | 49 mm. |
| Breadth | 53 " |
| Index (mesuranic) | 112.2. |

Alveolar or Gnathic Index.

| | |
|--|--------|
| Basi-alveolar | 84 mm. |
| Basi-nasal | 77 " |
| Index (prognathous to an extreme degree) | 109.1. |

Facial Index.

| | |
|---------------------------------|--------|
| Naso-mental distance | 97 mm. |
| Bi-zygomatic distance | 96 " |
| Index (leptoprosopic) | 101. |

The facial angle of Camper was not estimated.

There was no marked asymmetry.

Summary.

The type of skull is long-headed and narrow, with a lowly vault, the face narrow, with ape-like protrusion of the jaws (thick-lipped in life).

The nose was of medium breadth, and the orbits unusually high. The point of interest, which warrants the record, is the diminutive brain space available.

It is not in any sense a record such as Dr. Saunders's specimen, with a brain weighing 170 grammes (specific gravity of whole encephalon = 1036: Bucknil), but it is much smaller than an average case of microcephaly.

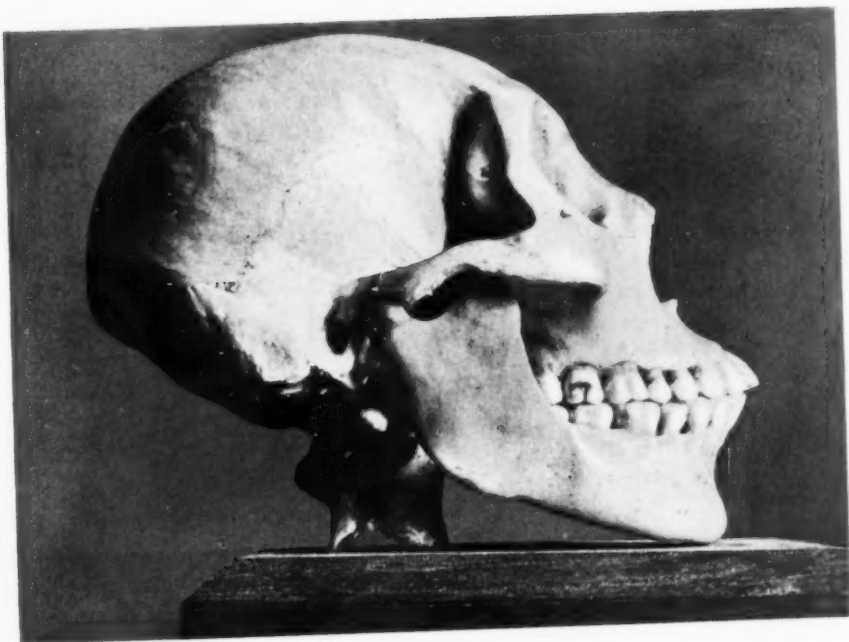


FIG. 1.

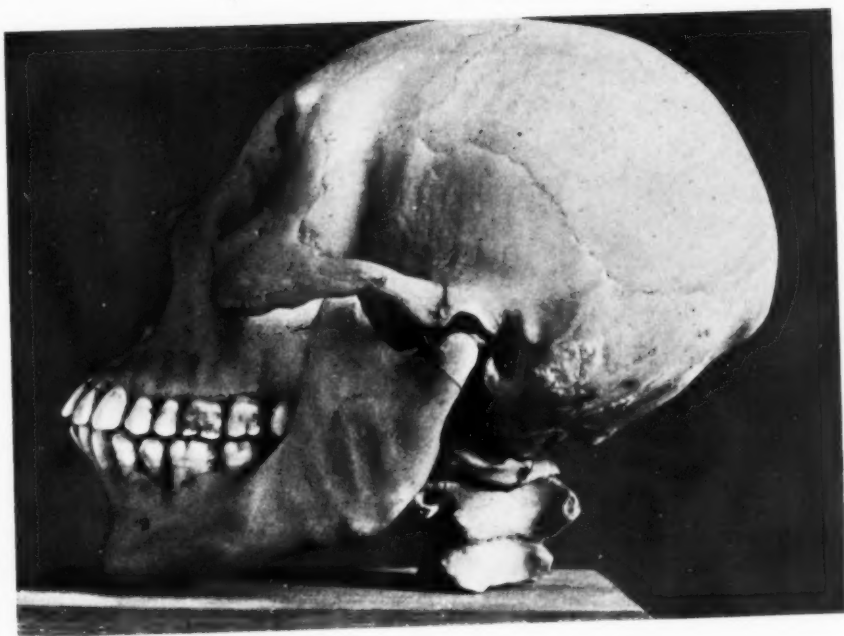


FIG. 2.

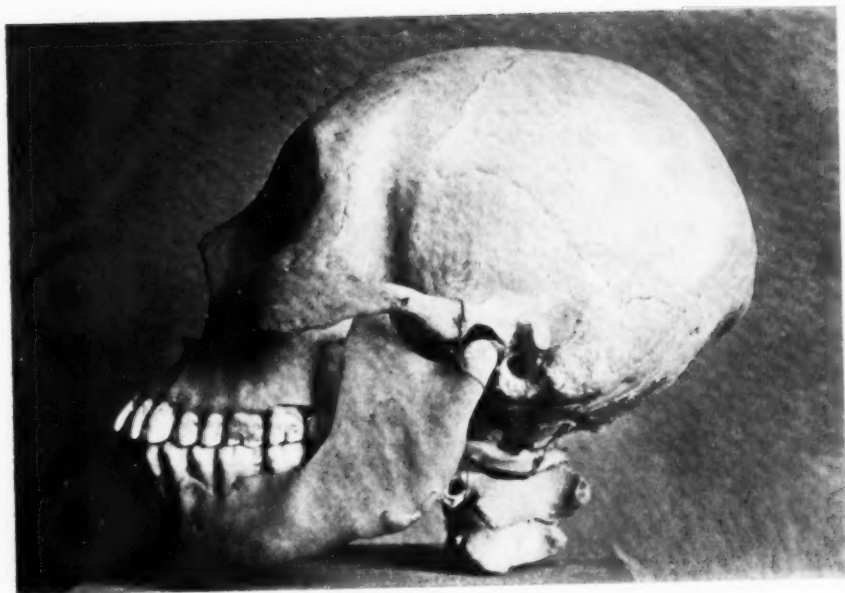


FIG. 3.

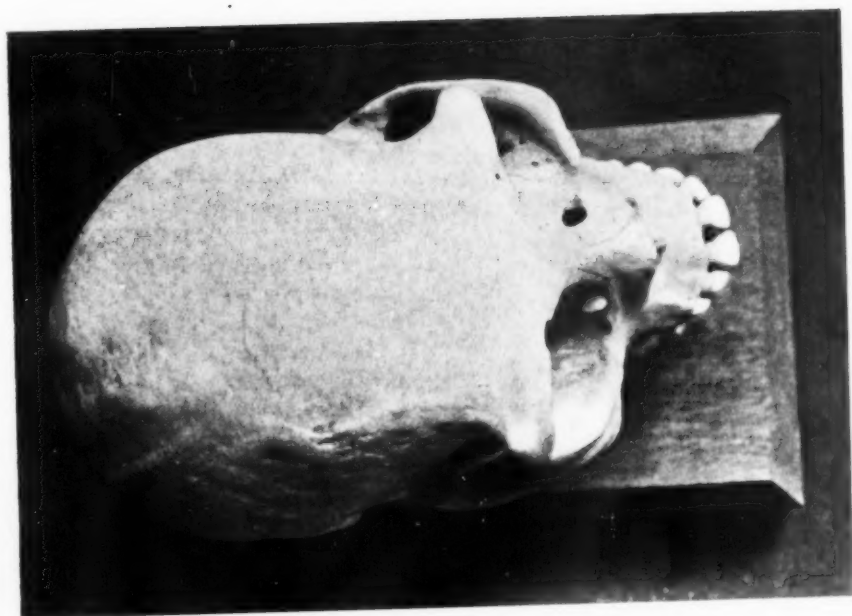


FIG. 4.

A CONTRIBUTION TO THE STUDY OF THE DIAMOND MACLE.

WITH A NOTE ON THE INTERNAL STRUCTURE OF DIAMOND.

By J. R. SUTTON, M.A., Sc.D., F.R.S.S.A., Hon. Memb. R.Met.S.,
Hon. Memb. S.A.S.C.E.

"Composite crystals often occur, in which the several portions have different orientations governed by regular and definite laws. When the crystallisation of a substance held in solution is hurried by rapid evaporation of the solvent, the crystals usually grow together in groups, in which the arrangement of the several members is purely accidental. But it was observed at a very early date that crystals of certain minerals, in particular those of cassiterite and spinel, are joined together in a regular and constant manner to form a well defined individual. . . .

"Romé de l'Isle was the first to attempt an explanation of the composite character of the crystals of spinel and cassiterite, and he introduced the word *macle* to denote a kind of composite crystal which we now call a twin. Werner employed the word *zwilling* (= a twin), at present used by German crystallographers, and later on Haüy introduced the word *hemitrope* (from *ἡμ* = half, and *τροπή* = a turn), for he perceived that the orientation of the two portions of every well-defined twin known to him is given by the following law: A complete crystal, bounded by the forms observable on the twin, is divided along a central plane which is parallel to a possible face; and the half on one side of the plane is then turned through 180° about the normal, the two halves remaining in contact to form the twin. This law gives in very many cases the relative orientation of the two portions united together in a twin crystal; it offers no suggestion as to the cause of twinning, and supplies no explanation of the growth of the twin" (Lewis, 'Crystallography,' 1899, p. 461).

It is rarely, however, that a diamond macle is equivalent to two halves of a complete crystal, or that the length of an edge is 1.225 times the thickness between two opposite triangular faces, or that its "central plane" is a plane at all. Mostly it is of tabular habit, and its aspect is pretty

much what would be obtained if two rough flakes, not necessarily of equal thickness—one from each of two opposite faces of an octahedron, or one from each of two opposite corners of a rhombic dodecahedron—were rotated 60° or 180° , either way round, and joined together. At the same time the opposite faces tend to accurate parallelism. Since very few diamonds have sharp edges it can be understood why the majority of diamond macles have not indented (swallow-tail) corners, the indentations having disappeared in the process which rounded the edges. Hence the corners of most of these macles are blunt; though not a few, and especially those with dodecahedral characteristics, taper gradually with a lenticular section to a sharp edge.

An uncommon sort of macle is known in which the central plane is not a hexagon but a perfect triangle larger than the parallel faces, and everywhere falling outside the orthogonal projection of the faces; and in this case (which is difficult to understand) the edge faces meet in fairly sharp edges and carry the usual facial triangular indentation (see Fig. 1).*

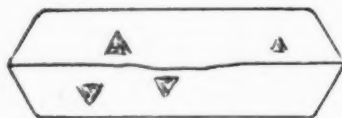


FIG. 1.—Wesselton glassy macle, enlarged six times.

Pretty often one of the halves of a macle projects beyond the other, as though the two halves had worked to combination planes of different size, or as though a flake from one diamond had been joined at random, excepting as to orientation, to a flake from another larger one. Fig. 2 is an illustration of a Wesselton macle of this kind. In Fig. 2 (A), CB and CF are the two halves seen edgewise. The projecting portion AD of the twinning plane is indented with shallow triangles standing the opposite way to those on the outer face EF, as shown in plan in Fig. 2 (B). That is to say, the lower half CF in Fig. 2 (A) partakes of the character of a proper octahedral tabular crystal. We should infer from this that either half may have grown independently of the other to some extent.

Fig. 3 shows an edge of a Bultfontein macle of a type intermediate between those of Figs. 1 and 2.

Frequently the edges of glassy macles are deeply indented with pyramidal terraced depressions, the triangles of one half being opposed base to base to those of the other half. Quite as often, however, only one of the halves has these depressions, the other half being quite independent of them.

* According to current theories this specimen would be regarded as a maced form of the plus and minus tetrahedron. Cf. Spencer, 'Ency. Brit.,' 1910, art. "Crystallography"; and Rutley's 'Mineralogy,' 1916, p. 70.

Composite types and irregular forms are common :

Ex. 1.—A nearly complete Bultfontein crystal with rounded edges and a "shield" face not indented with triangles. On a cleavage plane roughly

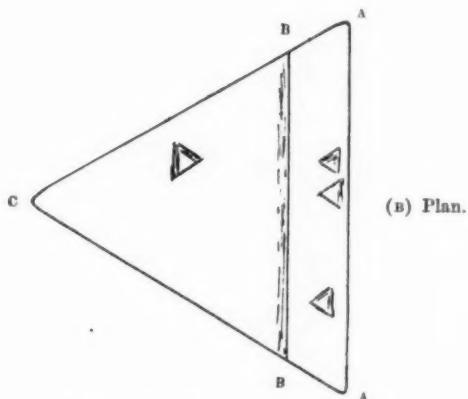
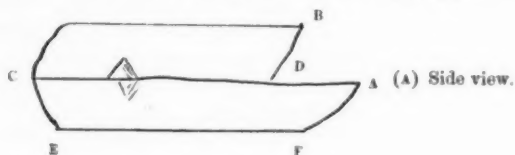


FIG. 2.—Wesselton macle, enlarged.

parallel to the shield a thin flake had grown macing the diamond. This flake was much less rounded than the rest and had numerous triangular indentations on its face.



FIG. 3.—A Bultfontein macle.

The dimensions of the diamond were :

Length of edge, 7.6 mm.

Thickness of whole diamond perpendicularly to the twinning plane,
6.3 mm.

Thickness of macing flake, 0.8 mm.

Ex. 2.—A macle with one half dodecahedral, the other half inclining to octahedral.

Length of edge, 6·5 mm.

Thickness, 3·8 mm.

Ex. 3.—In the case of many Dutoitspan macles the combination plane is almost circular in plan even when the faces are flat.

Ex. 4.—In the case of many Koffyfontein specimens, especially those of dodecahedral affinities, the combination plane is isosceles. Others are scalene. The spread dodecahedral macles from Jagersfontein often show the same irregularity.

The diamonds found in the principal mines of Griqualand West and the Orange Free State may be classified for convenience into two holohedral groups, namely octahedral and dodecahedral, albeit there is no hard and fast demarcation between them. Practically every octahedron carries

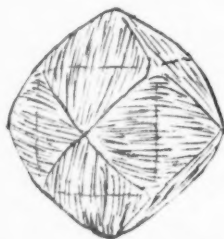


FIG. 4.—A typical large yellow diamond from Dutoitspan.

dodecahedral striations more or less developed, and nearly all dodecahedra show traces of an octahedral lineage; and this is so even when the dodecahedron declines into the tetrahexahedron, as in Fig. 4. From the infrequent octahedron on the one hand almost to the cube on the other there is an unbroken gradation. There are curious intermediate combinations, in which the edges of the rhombic dodecahedron, or tetrahexahedron, invade the faces of the octahedron, the said edges existing in embryo side by side with the (evanescent) triangular indentations belonging to the octahedron. These combinations have been mistaken for triakis- and hexakis-octahedra.

Of the macle the same may be said: There is the same unbroken progression from the one group to the other, including the illusory triakis- and hexakis-octahedra.

Generally speaking, swallow-tail corners on macles are a function of thickness. The thicker a macle relatively to the length of its edges, the greater the chance that the twinning plane is truly hexagonal. Otherwise the swallow-tails are only seen on macles whose octahedral characteristics are the most pronounced. Such macles will then have fourteen more or less

perfect faces. Oscillation types may have two octahedral faces and three rounded edges. Dodecahedral types may have no more than six, or twelve usually somewhat arched faces. These last are met with often enough at Jagersfontein, and occur also at Wesselton and Bultfontein, where they are most common in the smaller sizes.

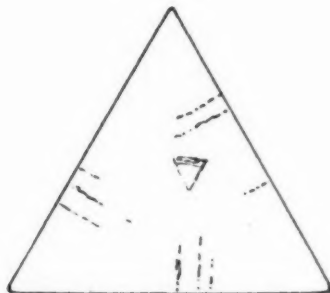


FIG. 5.—Macle, showing flawed edges.

The fracture of a macle is curious. A smashed diamond crystal, not maced, nearly always shows conchoidal fracture dominated by the so-called perfect cleavage. But in the case of the macle perfect cleavage scarcely counts, for it breaks easily enough parallel to an edge, and still more easily at right angles to an edge. In the first case the fracture is somewhat irregular and conchoidal; in the second it is remarkably direct, showing, moreover, a herring-bone "grain." Many spotted glassy macles have flawed

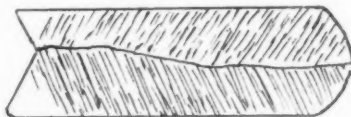


FIG. 6.—Herring-bone grain of macle.

edges, the flaws indicating the directions of easy breakage perpendicularly to the edges. Fig. 5 depicts a Wesselton macle with flawed edges, and Fig. 6 the grain of a macle broken at right angles to an edge.* It may be noted here that the straight breakage surface of a macle at right angles to an edge reveals much better than a natural edge does that the twinning plane is not necessarily a true plane at all, but rather an irregular surface, or at best a series of small planes on different horizons approximating to parallelism with the triangular faces of the macle.

* See the "Note on the Internal Structure of Diamond," below.

Among diamonds the macle-forming tendency does not appear to be strong, though some mines have it more than others. Some test-countings gave the following proportions by weight which macles bear to the total yield:

| | | | | | |
|------------------------|---|---|----------|----|-----------|
| Bultfontein | . | . | about | 1 | per cent. |
| Wesselton | . | . | " | 1½ | " |
| Dutoitspan | . | . | at least | 3 | " |
| De Beers and Kimberley | . | . | " | 5 | " |

The low percentage shown by Bultfontein is remarkable, that being the mine above all others where groups and clusters of diamonds abound, and where irregular twinning is so prominent a feature as to be almost a nuisance to the diamond merchant. The above percentages suggest, though they may not prove, that where regular twinning is most in evidence there irregular twinning will be least.

The most striking peculiarity of the diamond macle is of course its prevailing tabular habit. Untwinned crystals are pretty often flattish, and now and then, particularly at Bultfontein, tabular octahedra—the "portrait stones"* of the diamond market—are met with. These, saving that they are nearly always elongated, are equivalent to octahedra from which opposite facial blocks have been cleaved off, so that they have hexagonal faces. Measurements of four of these Bultfontein portrait stones gave the following dimensions:

| | Length. | | Breadth. | | Thickness. |
|----|---------|---|----------|---|------------|
| 1. | 11.0 | . | 6.0 | . | 2.5 mm. |
| 2. | 5.9 | . | 4.0 | . | 1.8 " |
| 3. | 9.7 | . | ? | . | 2.3 " |
| 4. | 7.7 | . | ? | . | 2.2 " |

As articles of merchandise they are much to be preferred to macles, but their philosophical interest is incomparably less. Superficially the chief differences between tabular crystals and macles are:

(1) The triangular indentations of the two opposite faces of a tabular crystal are oriented in opposition from any one point of view, whereas those of the macle are oriented the same way. This difference is very pleasingly shown if the crystal and the macle are held up to the light, side by side.

(2) The crystal breaks normally, the macle symmetrically.

(3) The crystal is glassy with a shining lustre, the macle not characteristically so.

(4) The macle is peculiarly tabular, the tabular crystal is rare.

The last clause is perhaps the most important. The ordinary crystal is by preference a regular solid whose axes are equal in length. And it seemed worth while to attempt to determine whether there is a standard of dimen-

* So called because they serve as glazing for small miniatures.

sions to which macles also tend to conform. Clearly there is no hard and fast necessity that a macle should be tabular seeing that now and then one comes across a macle which is made up exactly of two halves of a regular octahedron; but it is a question whether such a one is to be regarded as representing a standard from which all others are departures or whether it is itself a departure from whatever the standard may be. If it be the standard, then although the average spread (*i.e.* the ratio of length of edge to thickness) of all together may be much greater than its own, yet the actual numbers of the thinnest ones (ratio large) will be less than the actual numbers of the thickest ones (ratio small).

With the object of determining, first, the average spread, and, second, whether that average signifies a standard dimensional ratio or is merely a numerical median value, measurements of diamond macles of good geometrical symmetry have been made as opportunity offered. The results are set forth in the tables below.

TABLE 1.—*Octahedral Macles.*

| Mine. | Edge shorter than 5 mm. | | | Edge from 5 to 7.9 mm. | | | Edge 8 mm. and longer. | | |
|---------------|-------------------------|---------------|-------------|------------------------|---------------|-------------|------------------------|---------------|-------------|
| | No. | Average edge. | Spread E.T. | No. | Average edge. | Spread E.T. | No. | Average edge. | Spread E.T. |
| Koffyfontein | 8 | mm. 3.4 | 2.28 | 4 | mm. 6.3 | 2.38 | 1 | mm. 8.2 | 3.73 |
| Jagersfontein | 1 | 4.5 | 1.64 | 5 | 6.4 | 2.15 | 3 | 13.7 | 1.82 |
| Dutoitspan | 3 | 4.1 | 3.04 | 10 | 6.5 | 2.55 | 6 | 13.5 | 2.55 |
| Bultfontein | 50 | 3.6 | 2.74 | 40 | 6.5 | 2.82 | 15 | 9.3 | 2.49 |
| Wesselton | 9 | 3.6 | 2.86 | 27 | 6.6 | 2.66 | 31 | 9.9 | 2.57 |
| Total | 71 | 3.6 | 2.70 | 86 | 6.5 | 2.68 | 56 | 10.3 | 2.53 |

TABLE 2.—*Rhombic-dodecahedral Macles.*

| Mine. | Edge shorter than 5 mm. | | | Edge from 5 to 7.9 mm. | | | Edge 8 mm. and longer. | | |
|---------------|-------------------------|---------------|-------------|------------------------|---------------|-------------|------------------------|---------------|-------------|
| | No. | Average edge. | Spread E.T. | No. | Average edge. | Spread E.T. | No. | Average edge. | Spread E.T. |
| Koffyfontein | 8 | mm. 4.3 | 2.16 | 6 | mm. 6.0 | 2.68 | — | — | — |
| Jagersfontein | 4 | 4.4 | 2.15 | 9 | 6.8 | 2.44 | 6 | 9.6 | 2.33 |
| Dutoitspan | 3 | 3.8 | 1.85 | 7 | 6.5 | 2.23 | 6 | 12.4 | 1.99 |
| Bultfontein | 25 | 3.4 | 2.06 | 36 | 6.2 | 2.30 | 3 | 8.9 | 1.97 |
| Wesselton | 23 | 3.8 | 2.32 | 30 | 6.4 | 2.42 | 13 | 9.3 | 2.50 |
| Total | 63 | 3.7 | 2.18 | 88 | 6.3 | 2.38 | 28 | 10.0 | 2.30 |

Table 1 gives, for five mines, particulars of the ratio of length of edge (E) to thickness (T) of macles of prevaillingly octahedral character, arranged in three sets according to length of edge.

Table 2 gives corresponding particulars for macles of prevailingly rhombic-dodecahedral character.

From Tables 1 and 2 we gather that, on the whole, the smaller octahedral macles appear to have a slightly greater spread than the larger ones, the opposite being the case for the dodecahedral ones. Measurements of a very much larger number of specimens, however, would be required to definitely prove that it is so. What is clear is that the octahedral types have a larger spread than the dodecahedral; for the 213 macles of Table 1, with an average edge of 6.5 mm., have an average spread of 2.65, whereas the 179 macles of Table 2, with an average edge of 6 mm., have an average spread of 2.30. This is partly (but only partly) to be accounted for by the fact that the thicknesses in Table 1 are measured from face to face, whereas many of those of Table 2 had to be taken between two opposite coigns.

TABLE 3.—*Number of Octahedral Macles of Given Spread.*

| | E/T under 2. | 2 to 2.99. | 3 to 3.99. | 4 to 4.99. | 5 to 5.99. | 6 upwards. |
|-----------------|--------------|------------|------------|------------|------------|------------|
| Koffyfontein . | 6 | 3 | 4 | — | — | — |
| Jagersfontein . | 4 | 5 | — | — | — | — |
| Dutoitspan . | 4 | 10 | 5 | — | — | — |
| Bultfontein . | 17 | 52 | 28 | 6 | 1 | 1 |
| Wesselton . | 12 | 36 | 17 | 2 | — | — |
| Totals . | 43 | 106 | 54 | 8 | 1 | 1 |

For the whole 392 macles measured the average edge was 6.3 mm. and the spread 2.49. Whence it would appear that the average thickness of a macle is very closely one-half that of the regular octahedron standing on an equal base. The question now is, Has this ratio anything more than a chance significance? To test this query we must determine the actual number of specimens of given ratios in our list. Table 3, therefore, gives the numbers of octahedral macles in ascending grades of spread (E/T), and Table 4 gives corresponding particulars for the dodecahedral types.

A comparison of Tables 3 and 4 confirms the evidence of Tables 1 and 2 to the effect that, excepting at Jagersfontein, octahedral macles have a larger spread than dodecahedral ones. Indeed, in the case of two Bultfontein specimens included in the numbers of Table 4 the thickness was actually greater than the length of edge; and out of sixty-four Bultfontein dodecahedral macles no less than eight had a spread-ratio less than 1.5.

Again, of the whole number measured (= 392), considerably more than half had a spread-ratio between 2 and 3, whereas only about a quarter had a lesser spread. Thus it is proved that the average spread, 2.49, deduced

above is the spread to which the diamond macle tends to conform, and therefore that the *standard* macle is not rightly to be regarded as consisting of two halves of the standard octahedron. More than that, a macle which is equivalent to two halves of an octahedron is as much abnormal as a macle of four times its spread.*

It is a curious circumstance that although dodecahedral stones are common at Bultfontein, where quite a half of the yield is prevailingly of this type, and that Wesselton is a mine of stones inclining to the octahedral, yet more glassy and octahedral macles are found at the former place than at the latter. In fact, of the whole 169 Bultfontein macles dealt with in Tables 1 and 2, 105 (= 62 per cent.) were of the octahedral type, whereas only about a half of the Wesselton macles were so. Bultfontein octahedral macles, however, average smaller than Wesselton ones do—at any rate among diamonds exceeding one-tenth of a carat each.

TABLE 4.—Number of Dodecahedral Macles of Given Spread.

| — | E:T under 1. | 1 to 1'90. | 2 to 2'90. | 3 to 3'90. | 4 to 4'90. | 5 upwards. |
|-------------------|--------------|------------|------------|------------|------------|------------|
| Koffyfontein . . | — | 2 | 11 | 1 | — | — |
| Jagersfontein . . | — | 4 | 15 | — | — | — |
| Dutoitspan . . | — | 8 | 7 | 1 | — | — |
| Bultfontein . . | 2 | 27 | 26 | 8 | — | 1 |
| Wesselton . . | — | 15 | 41 | 10 | — | — |
| Totals . . | 2 | 56 | 100 | 20 | — | 1 |

The greatest spread-ratio hitherto observed by me is 6'37 (E = 5'1 mm., T = 0'8 mm.) on a glassy macle from Bultfontein. Spread-ratios of 5 on Bultfontein macles are not uncommon.

A Note on the Internal Structure of Diamond.

The grain which appears in herring-bone pattern on a broken macle is sometimes shown in straight pattern on a broken simple diamond crystal. This will be when the fracture happens to lie at right angles to an octahedron edge, *i.e.* parallel to a dodecahedral plane of symmetry. This grain is parallel to the plane of a continuous line of edges of the hexakisoctahedron; it is parallel to a plane joining any two opposite edges of the cube, or what is the same thing, to a plane joining any two opposite shorter diagonals of

* I am unable to say how this result compares with the average twin of spinel. Lewis (p. 467) observes that the twin of spinel *often* "acquires a more or less strongly-marked tabular habit by the disproportionate development of the faces parallel to the combination plane." An excellent little twin of Burma spinel in my possession has a spread-ratio of 1'40.

the rhombs of the dodecahedron. The grain, therefore, is equally inclined along six planary directions of the three rectangular axes.

Taking any complete set of six planary directions:

- (1) They meet a face of the octahedron in two sets of three each, of which one set is at right angles to the face, the other inclined $54^{\circ} 44'$ to the normal. The grain of the first set is inclined $35^{\circ} 16'$ to the normal; that of the second runs parallel to the surface.
- (2) They meet a face of the rhombic dodecahedron, one of them at right angles, the grain being also parallel to the shorter diagonal of the rhomb, one flush, as also the grain, with the longer diagonal, and four inclined at 30° to the normal, while the respective grainings of these are inclined at $54^{\circ} 44'$ to the edges.
- (3) They meet a face of the cube, two being at right angles to this, themselves intersecting at right angles, the grain of each being parallel to a diagonal of the face, and four at equal inclinations of 45° , as also their grainings.

Hence, having regard to these planary directions, if a diamond crystallises in dependent grained parallel laminae, then the octahedron, the rhombic dodecahedron and the cube, are the regular forms most likely to occur. Transition forms such as the triakis- and hexakis-octahedron, if there be such things, would be due to accelerated growth in the central parts of the planary directions cutting the faces of the octahedron; but there is no obvious reason why diamonds alleged to be of such forms should have the exquisite symmetry assigned to them in treatises on crystallography.

The geometrical patterns displayed on the faces of diamonds appear to be due to the grainings which run parallel to a face. Thus are derived the shallow triangular indentations on the faces of the octahedron—shallow, because their sides are normally parallel to similarly oriented dodecahedron faces, and the square indentations on the faces of the cube, these squares being apparently mostly confused by the intrusion of the grainings which meet the faces aslant. Again, the parallel striations appear whenever the grain of a planary direction runs flush with a face, as in the rhomb of the dodecahedron, and across a bevelled edge of the cube.

Rounded forms are entirely a dodecahedral effect. To be quite precise, there is no such thing as a rounded octahedron, though the term may pass for the sake of convenience. An octahedron can only be thicker through the middle of opposite faces than at the edges when its edges are terraced by the imposition, step upon step, of smaller and smaller triangular slices—the form which for some reason has been classed as a tetrahedral twin.* The

* The tetrahedral theory introduces much mental complexity into the study of the crystallisation of diamond. And although it may be invoked with some appearance of justification to explain a single-grooved edge to a diamond (*cf.* Lewis, p. 481), or a macle such as Fig. 1, it is less satisfactory when there are many grooves (and these with striated, not smooth edges), as is usually the case.

rounding arises solely from the *per saltum* curtailment of the areas of superimposed grained laminae on the rhombs of the dodecahedron, as can be easily seen under magnification: Imagine a number of tiny parallel rivulets, some a little stronger than others, of viscous matter to run from the middle each way nearly to the edge of a rhombic plane and to solidify; then a second lot to overflow them in the same direction though not so far; then a third lot, and a fourth, and so on, each lot in succession having a weaker driving "head." In the end we shall have a somewhat irregular-terraced sulcate elevation, rounded if the "head" has diminished at an increasing rate, sloping uniformly upwards to a ridge if the "head" has diminished uniformly. And this is about what the rippled, or sulcate surface of a typical Dutoitspan yellow dodecahedron looks like under the microscope. The rivulets here are actually due to the exposed grain of the diamond; the rounded elevation is that of the rounded dodecahedron; the uniform rise to a ridge is that of the tetrahexahedron.

Brewster seems to have been the first to detect the internal grain of a diamond. He noticed that the flat surface of a certain plano-convex lens of diamond was covered with minute parallel bands, and he concluded, not quite correctly, that "all the bands were the edges of veins or laminae whose visible terminations were inclined at different inclinations not exceeding two or three seconds [of arc] to the general surface." He added that "had this surface been an original face of the crystal there would have been nothing surprising in its structure" ('Phil. Trans.,' 1841). If, however, my argument above is sound, then the plane face of Brewster's lens must have been cut parallel to a face of the rhombic dodecahedron. Parallel bands would not have been seen on a plane cut in any other direction.*

The term "grain" is used in the diamond-cutting industry, yet not quite in the same sense as here. Eg. Cattelle ('The Diamond,' 1911) says, "Cut with or against the grain of a diamond, and the wheel makes little impression; it must be cut across the grain" (p. 114). Again, "Imperceptible as it is to an inexperienced eye, diamonds have a grain along which they can be split as wood is split, only much more evenly and exactly. This grain is parallel with the faces of the octahedra" (p. 126). Mineralogists have tried to say much the same of crystals in general in less homely language. Rutley (p. 41), *e.g.*, says that "In the plane of cleavage the molecules composing the mineral are closely packed together, whilst at right-angles to this plane the packing is not so close. This last direction is,

* Evidently Brewster's lens could not have been polished up to the vitreous stage so as to have acquired the "flowed layer of amorphous phase" which Beilby has suggested may be produced by purely mechanical means on the hardest crystal. Occasional dodecahedra from De Beers and Koffyfontein have an amazingly fine natural polish. Possibly their surfaces are in the vitreous stage. Boutan ('Le Diamant,' 1886, p. 37) ascribes the bands seen on Brewster's lens to multiple macleing. I hope to return to this matter again in a future paper.

therefore, a direction of least cohesion, and hence splitting or cleavage easily occurs along it." Also P. von Groth ('B. A. Report,' 1904) tells us that those planes which are parallel to the greatest density of structure—whatever that term may be supposed to mean precisely—are identical with the cleavage planes. Of course, what these authorities really mean to say is that the molecules are probably most closely packed in some given direction because a cleavage plane runs that way. By saying the other thing they put the cart before the horse. But it would seem that a diamond is most readily cleavable parallel to an octahedron face because the grain of each of three planary directions runs parallel to a face. It is not so easily cleavable parallel to the faces of the cube, because only the grain of each of two planary directions is parallel to a face, and it is still less easily cleavable parallel to a rhomb of the dodecahedron because the grain of only one planary direction runs that way; so that in the last case it is only across the thin edge of a macle that we should expect to get this sort of cleavage to the best advantage. All the same, it is surprising how good such cleavage from a simple crystal may be on occasion. Plates of cleavage parallel to a dodecahedral plane of symmetry are met with on the sorting tables in which both cleavage faces are as nearly parallel to each other as the faces of a portrait stone, and, moreover, are almost as natural looking as a face of the dodecahedron itself. Fractures parallel to a cube face are much less elegant as a rule.

We may summarise the last paragraph by saying that there are three orders of diamond cleavage:

First, that parallel to an octahedron face;

Second, that parallel to a cube face;

Third, that parallel to a dodecahedron face;

whence the cleavage of diamond is not so much a question of "density of structure," or concentration of molecules, as it is of array of molecules.

It may be of interest to note here that the great Robert Boyle failed to distinguish between the true grain of a diamond and the "grain" as understood by diamond cutters. He had observed the thin plates exposed on the broken surfaces of "New English *Granats*," "and to try whether this observation would hold even in the hardest Stones, I had recourse to a pretty big Diamond unwrought, which being plac'd in a Microscope, shew'd me the Commissures of the Flakes I look'd for, whose Edges were not so exactly dispos'd into a plain, but that some of them were very sensibly extant like little Ridges, but broad at the Top above the level of the rest. And these Parallel flakes together with their Commissures, I could in a somewhat large Diamond plainly enough discern even with my unassisted Eyes. And for further satisfaction I went to a couple of Persons, whereof the one was an Eminent Jeweller, and the other an Artificer, whose Trade was to cut and polish Diamonds, and they both assur'd me upon their

repeated and constant Experience, and as a known thing in their Art, that 'twas almost impossible (though not to break, yet) to *split* Diamonds, or cleave them smoothly cross the Grain (if I may so speak) but not very difficult to do it at one stroke with a Steeled Tool, when once they had found out from what part of the Stone, and towards what part the splitting Instrument was to be impell'd: By which 'tis evident that Diamonds themselves have a grain, or a flaky Contexture not unlike the *fissility*, as the Schools call it, in Wood" ('An Essay about the Origine and Virtues of Gems,' 1672, p. 21).

If the grain of a diamond, as revealed either by a fracture at right angles to an edge of the octahedron or by the natural face of the dodecahedron, represents lines of crystal growth (as seems not unreasonable as a first assumption), then it follows that the proximate primitive form of diamond is not an octahedron but a six-rayed figure defining cubical space—each ray joining the mid points of pairs of opposite edges of the cube and delineating the respective directions of accretion. Thus let AG, Fig. 7, be a cubical ray space (or space lattice), $a, b, c, d \dots$, the mid points of the respective edges. Then am, bn, ck, dl, eg, fh , are the directions of the rays. The crystallisation may be supposed to proceed by successive symmetrical impositions, edge to edge, of like cubical spaces containing the rays, each cubical ray space being surrounded by twelve others, that is, a second ray space $A'G'$ will be applied to AG in such a way that $E'F'$ lies along DC, a third $A''G''$ so that $A''B''$ lies along HG, and so on. The overall outline of the first 13 ray-spaces will define a cubical space equal to 27 primitive cubes of which 14 are empty. The addition now of a ray space opposite each face of the central one gives an octahedron of 17 ray spaces. If, further, we may venture to regard $a, b, c, d \dots$, each as indicating the place of a carbon particle, then each particle in a diamond crystal will be surrounded symmetrically by six others $b, n \dots$, at equal distances p (where p is the length of an edge of the cube), in directions $db, dn \dots$, parallel to the edges of the cube; by eight others $a, c, h, e \dots$, at equal distances $p/\sqrt{2}$, in directions $da, dc, dh, de \dots$, parallel to the edges of the octahedron; by twelve others, R, S, \dots , at equal distances $\sqrt{3}p$ in directions $dR, dS, dT, dU \dots$ (where dR, dS pass through P and Q the middle points of the cubic faces AF, DG; and dT, dU , are parallel to BQ, BP) parallel to the edges of the rhombic dodecahedron. In short $dn (=p)$, $dl (= \sqrt{2}p)$,* $dS (= \sqrt{3}p)$, delineate in magnitude and direction one edge of a cubical, octahedral, and dodecahedral space respectively. Again each particle in the crystal of this proximate structure is surrounded by 32 others, the whole forming a system of 33 contiguous particles. An interesting feature of the configuration is the

* $dl = 2 da = 2 (p/\sqrt{2})$.

fourfold grouping of six particles in a ring, by which every particle is at a corner of each of four hexagonal rings of six particles apiece in one plane, of which $d h m l f a$ is one.

Note.—For any assigned volume $R : C : O = 118 : 105 : 100$,
 where R is the surface of the rhombic dodecahedron,
 where C is the surface of the cube,
 where O is the surface of the octahedron.

This is perhaps as far as inference, based on mere eye observations of fracture, can carry any theory of the internal structure of diamond; and such a theory could only be proximate—in other words, it could tell us

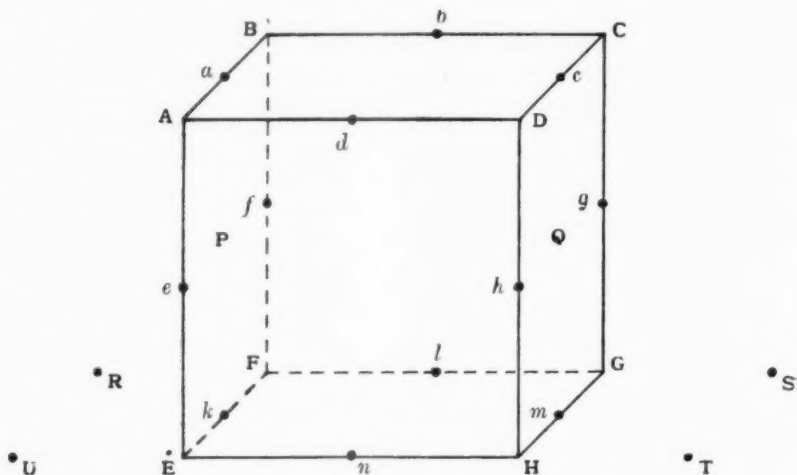


FIG. 7.—Grouping of carbon particles in diamond.

nothing of why the carbon particles should spread in a six-rayed framework, nor whether the particles may be regarded as ultimate atoms. A search for outside evidence bearing on this point did not at first sight seem to hold out much encouragement seeing that most published accounts of the diamond are wrong in their facts and, therefore, not likely to be right in their theories. Bragg's fundamentally important X-ray work on the structure of the diamond ('B. A. Report,' 1913) proved, however, to contain the sort of evidence that was required. It was perhaps unfortunate for me that owing to various distractions, arising mostly because of the war, I had overlooked his results before working out—and writing out as above—my own; but otherwise there is some satisfaction in finding that eye observations alone can carry a theory so far as it does. Bragg deduces a somewhat more

intricate grouping of atoms than that of the "particles" shown in Fig. 7. He finds a primitive cube, and draws it so that the points C, D, H, G, of Fig. 7 would be the mid points of its edges, and then deduces atoms correspondingly with $a, b, c, d, e, f, g, h, k, l, m, n$, but finds another atom point at the mid point of PQ, together with four others asymmetrically placed. To quote his own words: "When all the information is put together we find that the element of volume of the diamond is a face-centred cube; a cube having, that is to say, a carbon atom at each corner and one in the middle of each face. In the same cube are also four carbon atoms at the centres of four of the eight small cubes into which the large cube may be divided." In other words his cube coincides with mine excepting that its outline is shifted aside by half an edge, and that it contains five extra atoms which are not represented by particles in my drawing, and which I have been unable to derive. The spacing between the planes of atoms parallel to the faces of the cube (100), the dodecahedron (110) and the octahedron (111) is the same as for the "particles," namely as $1 : \sqrt{2} : \sqrt{3}$, whether the five extra atoms are included or not.

By placing a particle at the origin (O) of the six-rayed figure, *i. e.* at the centre of the cube in Fig. 7, we should have

$$\begin{aligned} dO : db : dg &= p/\sqrt{2} : p : \sqrt{3}p/\sqrt{2} \\ &= 1 : \sqrt{2} : \sqrt{3}. \end{aligned}$$

In this case successive ray-spaces might be placed face to face, whence the juxtaposition of adjacent halves of the ray-spaces would give a true lattice of face-centred cubes. The outside halves, however, would be derelict and the development of the octahedron not easily imaginable.

Rutherford seems to have had some difficulty with the structure found by Bragg, for in describing it ('Ann. Rep. Smithsonian Inst.,' 1915) he calls it cubical but complicated, and the "atoms are all equidistant, but the general arrangement differs markedly from that of rock salt. It is seen that each carbon atom is linked with four neighbours in a perfectly symmetrical way, while the linking of six carbon atoms in a ring is also obvious from the figure. The distance between the plates containing atoms is seen to alternate in the ratio 1:3." But neither this account nor the picture of the model made to illustrate it seems quite to agree with what Bragg said.

NOTE ON CARBOLIC ACID AS A FIXATIVE FOR
HISTOLOGICAL PREPARATIONS.

BY C. LAWRENCE HERMAN.

During 1912 whilst working in the Laboratory for Experimental Pathology in Vienna, I was led to investigate the condition of the colloid contents of the thyroid follicle, especially when subjected to different methods of fixation.

Important deductions had been drawn from the appearance of the colloid as seen under the microscope as to its behaviour to stains, and more especially as to being more or less fluid under certain conditions.

This applied particularly to pathological changes, and I wished to determine in how far this was caused by the methods of preparation employed.

I accordingly examined sections of the thyroid after fixation by a large number of different substances in varying dilutions.

On the outbreak of the war I had to leave Vienna very hurriedly and my notes and records had to be left behind and I fear have been lost.

However, without going into details at present, I may say in general I found that most of the fixatives used, including the most frequently employed and customary ones, presented some or other disadvantage, either causing shrinking or vacuolation, or the solution of the colloid wholly or in part; while several interfered with the staining especially of the colloid.

In the case of carbolie acid, however, a good and complete fixation was obtained without shrinking or the production of vacuoles and with very good optical differentiation of cell structures. Moreover, the staining reaction was not interfered with.

On the contrary the various stains used were taken up readily and completely.

Further application of this method to various tissues and organs—the liver, stomach, the abdominal organs generally, and the central nervous system—gave exceedingly gratifying results, especially in cases where rapid penetration and fixation is of advantage, such, for example, as the rat's testicle.

Though carbolic acid was discovered in 1834 (by Runge), it did not come into general use till 1866, when Lord, then Mr., Lister introduced it into practice in the treatment of wounds as a general surgical antiseptic.

Carbolic acid is one of the hydroxyl compounds of benzol, and, like several of this series, is a strong antiseptic and preservative. It is easily soluble in water (1-88 at 16°), and in oils and several other media.

It acts as a general protoplasm poison, and even in dilute solutions kills protozoa quickly unless in extremely attenuated dilutions.

Plant cells are acted on in the same way; ciliated epithelial cells and spermatozoa are killed at once.

It precipitates protein both in solution and in the cells, and does not, like so many substances used in microscopical technique, enter into combination with the albumen to form a fresh compound. It can consequently be washed out with comparative ease.

As a result it penetrates more rapidly and completely into the tissues than metallic or other substances which form insoluble compounds with albumen.

It fixes both the cytoplasm and the nucleus without alteration or distortion, while it leaves all cell structure well defined and clear.

It is of more than ordinary interest to note here that Lister, then engaged in developing his epoch-making life's work, antiseptic surgery, demonstrated in some early experiments the avidity with which epidermis and hair absorbed carbolic acid from its watery solution.

He packed human hair in a test-tube, then covered it with a 5 per cent. carbolic acid solution; in half an hour one-half of the carbolic acid had been extracted from the solution.

In another experiment he packed a glass tube open at both ends with hair, and whilst it stood upright carbolic acid solution was poured in at the upper end. For some time the liquid which flowed from the lower end of the tube contained no carbolic acid at all.

At the same time that carbolic acid is a good fixative it is a preservative, and as such it has been largely used.

I was much interested to learn from Hofrat Professor Paltauf, the distinguished head of the Laboratory for Experimental Pathology, Vienna, that he had examined tissues from an exhumed body which had been soaked in carbolic and buried for some considerable time. The body had been covered with carbolic acid in the hopes of destroying all traces of a crime. He had been much surprised to find the remarkable state of preservation of the tissues, and microscopical sections, especially of the stomach, etc., gave particularly good results.

The cause of this was not fully appreciated at the time, but was made clear on an examination of my preparations.

Largely used in microscopical technique both in histological and

bacteriological work, its remarkable power of fixing and preserving tissues for examination under the microscope have not been appreciated, and, if we except the fixative of Pappenheim, in which indeed it is mixed with corrosive sublimate, has not been made use of.

As an antiseptic and preservative Kaiser adds 1·0 carbolic acid to 100·0 gelatine for imbedding, and added to saccharine solution or glycerine jelly it is used for mounting sections.

Weigert uses carbolic-xylol to clear celloidin sections, and it has been mixed with cedar and other oils to act as a clearing agent. Moreover, it is used for dehydrating sections.

Its principal use in microscopy, however, has been as an addition to various aniline dyes to facilitate the staining especially of bacteria, as in the well-known stains, carbol-fuchsin and carbol-methylene-blue, etc.

A solution is easily prepared from Calvert's carbolic acid (I generally use No. 1) or from phenol. The crystals are melted by placing the bottle containing the carbolic in boiling water. Liquefaction quickly takes place. The desired quantity can be readily poured out and measured.

Carbolic acid acts best in 5 per cent. solutions; any lower percentage gives unsatisfactory results.

The preparation to be fixed, preferably small, is left in the fluid from three to six hours; smaller pieces of tissue do not require so long. I have had excellent results with a two hours' fixation, but no harm is done by leaving it longer than six hours in the fluid.

As carbolic acid is freely absorbed by the tissues, the amount of the fluid used must be liberal.

Subsequent washing out is not needed, and the after-treatment follows the usual course—dehydration in the customary manner and clearing by xylol, or preferably by cedar oil, before imbedding.

Briefly, the advantages of carbolic acid as a fixative are:

- (1) Rapid penetration and efficient fixation with the least distortion or alteration of tissue.
- (2) Good optical differentiation, all cell structures as well as the cell wall remaining well and clearly defined.
- (3) The readiness with which good staining is obtained after fixation by this method.

LITERATURE.

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NOTE ON A SUM OF PRODUCTS WHICH INVOLVES
SYMMETRICALLY THE N TH ROOTS OF 1.

BY SIR THOMAS MUIR, LL.D.

- (1) Each of the products in question consists of n factors of the form

$$a_1 + a_2\theta + a_3\theta^2 + \dots + a_n\theta^{n-1},$$

where θ is an n th root of unity; and the sum includes n of these products, any two of which differ merely in that the n th root of unity appearing in the one is different from that which appears in the other. This is the same as saying that if ω be a primitive n th root of 1, the sum to be considered is

$$\sum_{s=1}^{s=n} \prod_{r=1}^{r=n} (a_{r1} + a_{r2}\omega^s + a_{r3}\omega^{2s} + \dots + a_{rn}\omega^{(n-1)s}).$$

- (2) As a preliminary it is necessary to recall the notation of a class of functions studied in 1885 under the not very appropriate name of "bipartites," the word being adopted in consequence of it having been found that bilinear forms, called "bipartites" by Cayley, were viewable as functions of the kind in question when of the third degree.*

- (3) The function of degree-order $2, n$ is

$$\frac{a_1, a_2, \dots, a_n}{b_1, b_2, \dots, b_n},$$

its equivalent in ordinary notation being

$$a_1b_1 + a_2b_2 + \dots + a_nb_n;$$

the function of degree-order $3, 4$ is

$$\begin{array}{cccc|c} a_1 & a_2 & a_3 & a_4 & f_1 \\ b_1 & b_2 & b_3 & b_4 & \\ c_1 & c_2 & c_3 & c_4 & f_2 \\ d_1 & d_2 & d_3 & d_4 & f_3 \\ e_1 & e_2 & e_3 & e_4 & f_4 \end{array}$$

which equals

$$\frac{a_1 a_2 a_3 a_4}{b_1 b_2 b_3 b_4} \cdot f_1 + \frac{a_1 a_2 a_3 a_4}{c_1 c_2 c_3 c_4} \cdot f_2 + \dots$$

and thus represents

$$a_1b_1f_1 + \dots + a_4e_4f_4,$$

the sum of sixteen terms got by taking each element of the square array

* 'Trans. R. Soc. Edinburgh,' xxxii, pp. 461-482.

and multiplying it by the outside elements which are in the same column or row with it: the function of degree-order 4,2 is

$$\begin{array}{c|c|c} a & b & \\ \hline c & d & g \ i \\ \hline e & f & h \ j \\ \hline & & k \ l \end{array} \quad \text{or} \quad \begin{array}{c|c|c} a & b & k \ l \\ \hline c & d & g \ i \\ \hline e & f & h \ j \\ \hline & & \end{array}$$

which equals

$$k \cdot \begin{array}{c|c|c} a & b & \\ \hline c & d & g \\ \hline e & f & h \end{array} + l \cdot \begin{array}{c|c|c} a & b & \\ \hline c & d & i \\ \hline e & f & j \end{array}$$

and therefore stands for

$$acgk + acil + aehk + aejl + bdgk + bdil + bfhk + bfjl:$$

and so on, the number of terms in the final expansion being n^{m-1} when the degree-order is m, n .

(4) The most interesting occurrence of the functions in analysis is as the elements of product-determinants: for example,

$$\begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix} \cdot \begin{vmatrix} p_1 & p_2 & p_3 \\ q_1 & q_2 & q_3 \\ r_1 & r_2 & r_3 \end{vmatrix} = \begin{vmatrix} a_1 a_2 a_3 & a_1 a_2 a_3 & a_1 a_2 a_3 \\ p_1 p_2 p_3 & q_1 q_2 q_3 & r_1 r_2 r_3 \\ b_1 b_2 b_3 & b_1 b_2 b_3 & b_1 b_2 b_3 \\ p_1 p_2 p_3 & q_1 q_2 q_3 & r_1 r_2 r_3 \\ c_1 c_2 c_3 & c_1 c_2 c_3 & c_1 c_2 c_3 \\ p_1 p_2 p_3 & q_1 q_2 q_3 & r_1 r_2 r_3 \end{vmatrix},$$

$$\begin{vmatrix} a_1 & a_2 \\ b_1 & b_2 \end{vmatrix} \cdot \begin{vmatrix} h_1 & h_2 \\ k_1 & k_2 \end{vmatrix} \cdot \begin{vmatrix} m_1 & m_2 \\ n_1 & n_2 \end{vmatrix} = \begin{vmatrix} a_1 a_2 & a_1 a_2 & a_1 a_2 \\ h_1 h_2 & h_1 h_2 & h_1 h_2 \\ k_1 k_2 & k_1 k_2 & k_1 k_2 \\ b_1 b_2 & b_1 b_2 & b_1 b_2 \\ h_1 h_2 & h_1 h_2 & h_1 h_2 \\ k_1 k_2 & k_1 k_2 & k_1 k_2 \end{vmatrix},$$

$$\begin{vmatrix} a_1 & a_2 \\ b_1 & b_2 \end{vmatrix} \cdot \begin{vmatrix} h_1 & h_2 \\ k_1 & k_2 \end{vmatrix} \cdot \begin{vmatrix} m_1 & m_2 \\ n_1 & n_2 \end{vmatrix} \cdot \begin{vmatrix} x_1 & x_2 \\ y_1 & y_2 \end{vmatrix} = \begin{vmatrix} a_1 a_2 & x_1 x_2 & a_1 a_2 & y_1 y_2 \\ h_1 h_2 & m_1 n_1 & h_1 h_2 & m_1 n_1 \\ k_1 k_2 & m_2 n_2 & k_1 k_2 & m_2 n_2 \\ b_1 b_2 & x_1 x_2 & b_1 b_2 & y_1 y_2 \\ h_1 h_2 & m_1 n_1 & h_1 h_2 & m_1 n_1 \\ k_1 k_2 & m_2 n_2 & k_1 k_2 & m_2 n_2 \end{vmatrix};$$

but several other distinct occurrences have been pointed out.*

(5) Let us now turn to the multiplying of

$$a_1 + a_2 \omega + a_3 \omega^2 + \dots + a_n \omega^{n-1}$$

by another expression of the like kind

$$b_1 + b_2 \omega + b_3 \omega^2 + \dots + b_n \omega^{n-1}.$$

* For example, 'Proc. Lond. Math. Soc.,' xvi, pp. 276-286.

The law of formation of the continued products is thus evident, and we can with confidence affirm the next result to be

$$\begin{aligned}
 & (a_1 + a_2\omega + a_3\omega^2 + a_4\omega^3)(\quad)(\quad)(d_1 + d_2\omega + d_3\omega^2 + d_4\omega^3) \\
 &= \frac{a_1 a_2 a_3 a_4}{b_1 b_4 b_3 b_2} \begin{vmatrix} c_1 & c_2 & c_3 & c_4 \\ b_2 & b_1 & b_4 & b_3 \\ b_3 & b_2 & b_1 & b_4 \\ b_4 & b_3 & b_2 & b_1 \end{vmatrix} \begin{vmatrix} d_1 & d_2 & d_3 & d_4 \\ d_2 & d_1 & d_4 & d_3 \\ d_3 & d_2 & d_1 & d_4 \\ d_4 & d_3 & d_2 & d_1 \end{vmatrix} \begin{vmatrix} 1 \\ \omega \\ \omega^2 \\ \omega^3 \end{vmatrix}
 \end{aligned}$$

(7) Using Σ before any one of the products thus dealt with to indicate that ω is to be replaced by ω^2 , ω^3 , ω^4 , and the results to be added to the original, we obtain from §5

$$\begin{aligned}
 & \Sigma(a_1 + a_2\omega + a_3\omega^2 + a_4\omega^3)(b_1 + b_2\omega + b_3\omega^2 + b_4\omega^3) \\
 &= \frac{a_1 a_2 a_3 a_4}{b_1 b_4 b_3 b_2} \begin{vmatrix} 1 & 1 & 1 & 1 \\ \omega & \omega^2 & \omega^3 & 1 \\ \omega^2 & 1 & \omega^2 & 1 \\ \omega^3 & \omega^2 & \omega & 1 \end{vmatrix} \\
 &= 4 \cdot \frac{a_1 a_2 a_3 a_4}{b_1 b_4 b_3 b_2},
 \end{aligned}$$

because of the vanishing of $1 + \omega + \omega^2 + \dots + \omega^{n-1}$. Similarly from §6 there are got

$$\begin{aligned}
 & \Sigma(a_1 + a_2\omega + a_3\omega^2 + a_4\omega^3)(c_1 + c_2\omega + c_3\omega^2 + c_4\omega^3) \\
 &= 4 \cdot \frac{a_1 a_2 a_3 a_4}{b_1 b_4 b_3 b_2} \begin{vmatrix} c_1 \\ b_2 & b_1 & b_4 & b_3 \\ b_3 & b_2 & b_1 & b_4 \\ b_4 & b_3 & b_2 & b_1 \end{vmatrix}
 \end{aligned}$$

and $\Sigma(a_1 + a_2\omega + a_3\omega^2 + a_4\omega^3)(d_1 + d_2\omega + d_3\omega^2 + d_4\omega^3)$

$$= 4 \cdot \frac{a_1 a_2 a_3 a_4}{b_1 b_4 b_3 b_2} \begin{vmatrix} c_1 & c_2 & c_3 & c_4 \\ b_2 & b_1 & b_4 & b_3 \\ b_3 & b_2 & b_1 & b_4 \\ b_4 & b_3 & b_2 & b_1 \end{vmatrix} \begin{vmatrix} d_1 & d_2 & d_3 & d_4 \\ d_2 & d_1 & d_4 & d_3 \\ d_3 & d_2 & d_1 & d_4 \\ d_4 & d_3 & d_2 & d_1 \end{vmatrix}$$

The last is the main result, the others being derivable from it by specialisation.

(8) As a consequence of the preceding, some interest attaches to determinants whose elements are of the type

$$a_1 + a_2\omega + a_3\omega^2 + \dots + a_n\omega^{n-1}.$$

Confining ourselves to the third order, merely from considerations of space, let us examine the determinant

$$\begin{vmatrix} a_1 + a_2\omega + a_3\omega^2 & b_1 + b_2\omega + b_3\omega^2 & c_1 + c_2\omega + c_3\omega^2 \\ d_1 + d_2\omega + d_3\omega^2 & e_1 + e_2\omega + e_3\omega^2 & f_1 + f_2\omega + f_3\omega^2 \\ g_1 + g_2\omega + g_3\omega^2 & h_1 + h_2\omega + h_3\omega^2 & k_1 + k_2\omega + k_3\omega^2 \end{vmatrix}.$$

By partitioning it into twenty-seven determinants with monomial elements it is readily seen to be expressible in the form

$$P + Q\omega + R\omega^2$$

where P, Q, R are each the sum of nine determinants, and in particular

$$\begin{aligned} P = & |147| + |258| + |369| \\ & + |159| + |267| + |348| \\ & + |168| + |249| + |357|, \end{aligned}$$

if $|mnr|$ stand for the determinant whose columns are the m^{th} , n^{th} , r^{th} of the 3-by-3² array

$$\begin{array}{ccc|ccc|ccc} a_1 & a_2 & a_3 & b_1 & b_2 & b_3 & c_1 & c_2 & c_3 \\ d_1 & d_2 & d_3 & e_1 & e_2 & e_3 & f_1 & f_2 & f_3 \\ g_1 & g_2 & g_3 & h_1 & h_2 & h_3 & k_1 & k_2 & k_3. \end{array}$$

It follows therefore that, if we use Σ as above we have

$$P = \frac{1}{3} \sum \begin{vmatrix} a_1 + a_2\omega + a_3\omega^2 & b_1 + b_2\omega + b_3\omega^2 & c_1 + c_2\omega + c_3\omega^2 \\ d_1 + d_2\omega + d_3\omega^2 & e_1 + e_2\omega + e_3\omega^2 & f_1 + f_2\omega + f_3\omega^2 \\ g_1 + g_2\omega + g_3\omega^2 & h_1 + h_2\omega + h_3\omega^2 & k_1 + k_2\omega + k_3\omega^2 \end{vmatrix}.$$

Instead, however, of partitioning the determinant we may take the six terms of its ordinary expansion, and, these being of the type

$$(a_1 + a_2\omega + a_3\omega^2)(e_1 + e_2\omega + e_3\omega^2)(k_1 + k_2\omega + k_3\omega^2),$$

we can make use of our old theorem regarding such products, and thus arrive at the result

$$\begin{aligned} & \frac{1}{3} \sum \begin{vmatrix} a_1 + a_2\omega + a_3\omega^2 & b_1 + b_2\omega + b_3\omega^2 & c_1 + c_2\omega + c_3\omega^2 \\ d_1 + d_2\omega + d_3\omega^2 & e_1 + e_2\omega + e_3\omega^2 & f_1 + f_2\omega + f_3\omega^2 \\ g_1 + g_2\omega + g_3\omega^2 & h_1 + h_2\omega + h_3\omega^2 & k_1 + k_2\omega + k_3\omega^2 \end{vmatrix} \\ &= \frac{a_1 a_2 a_3}{e_1 e_2 e_3} \frac{b_1 b_2 b_3}{f_1 f_2 f_3} \frac{c_1 c_2 c_3}{k_1 k_2 k_3} + \frac{a_1 a_2 a_3}{e_1 e_2 e_3} \frac{b_1 b_2 b_3}{f_1 f_2 f_3} \frac{c_1 c_2 c_3}{k_1 k_2 k_3} \omega \\ &+ \frac{a_1 a_2 a_3}{e_1 e_2 e_3} \frac{b_1 b_2 b_3}{f_1 f_2 f_3} \frac{c_1 c_2 c_3}{k_1 k_2 k_3} \omega^2 + \frac{a_1 a_2 a_3}{e_1 e_2 e_3} \frac{b_1 b_2 b_3}{f_1 f_2 f_3} \frac{c_1 c_2 c_3}{k_1 k_2 k_3} \omega^2 \\ &+ \frac{a_1 a_2 a_3}{e_1 e_2 e_3} \frac{b_1 b_2 b_3}{f_1 f_2 f_3} \frac{c_1 c_2 c_3}{k_1 k_2 k_3} \omega^2 + \frac{a_1 a_2 a_3}{e_1 e_2 e_3} \frac{b_1 b_2 b_3}{f_1 f_2 f_3} \frac{c_1 c_2 c_3}{k_1 k_2 k_3} \omega^2 \\ &+ \frac{a_1 a_2 a_3}{e_1 e_2 e_3} \frac{b_1 b_2 b_3}{f_1 f_2 f_3} \frac{c_1 c_2 c_3}{k_1 k_2 k_3} \omega^2. \end{aligned}$$

Denoting this bipartite aggregate by T, we consequently have in regard to the above-mentioned 3-by-3² array the curious equality

$$P = T$$

connecting determinants and bipartites.

RONDEBOSCH, S.A.,

July 22, 1919.

NEW AND INTERESTING SOUTH AFRICAN MOSSES.

By H. N. DIXON, M.A., F.L.S.

(With Plates XI and XII.)

I have during recent years received a considerable number of mosses from different collectors in South Africa, principally from Prof. Wager, of Transvaal University College, Pretoria, and a considerable collection, including some very interesting plants, made in the neighbourhood of Tjumie, in the Highlands of Cape Province, by the Rev. Jas. Henderson, of Lovedale, his son Donald Henderson, and other members of his family, and sent to me by the Rev. D. Lillie. More recently Mr. T. R. Sim has sent me a considerable number of specimens collected by himself and his friends, and also comprising a good many novelties. These and a few others are included in this paper.

I have not confined myself to the description of new species; in addition to these and a few others calling for special notice, I have included notices of other species for the sake of distribution records. I have not intentionally included such as are obviously common or widely distributed species; but the distribution of even the commoner mosses in South Africa can hardly be said to be worked out at all systematically, and one who has not collected on the spot may easily be misled as to facts of distribution, and may, I hope, be as easily forgiven for unwittingly including some records which to South African bryologists may seem superfluous.

Prof. Wager in his 'Check-List of the Mosses of South Africa' has given a few localities for some species, but anything like a conspectus of the moss-flora of South Africa has not yet appeared, and is greatly to be desired. Mr. Sim has laid the foundation for this in his 'Handbook of the Bryophyta of South Africa,' Parts I and II, dealing so far principally with the genera; it is much to be hoped that he may be able, by the publication of the third part, to bring the work to such a completion that the student of South African bryology may have a real compendium of the mosses of this region with their geographical distribution as far as it is known.

For such a work one of the essential preliminaries is to clear up

numerous problems as to the identity or otherwise of certain of the South African species with allied species from the North Temperate regions. I am not inclined to think that this identity is likely to be found in very many species; at the same time I am convinced that it exists between a certain number of plants where it has not hitherto been recognised, and some of Mr. Sim's gatherings from high mountain elevations have gone a good way to confirm this. I am quite convinced for example that *Bryum afro-alpinum* Rehm. (and probably *B. Wilmsii* C. M. also) is identical with *B. alpinum* Huds.; while several gatherings of another species are to me entirely indistinguishable from *B. Muehlenbeckii* Bry. Eur.; *Polytrichum flexicaule* C. M. is quite inseparable from *P. commune* L., while more than one of the forms of *Tortula* described by C. Mueller from South Africa are I think entirely identical with *T. ruralis* (L.) (*Barbula afro-ruralis* C. M.; *B. leucostega* C. M.). One or two other identifications with European species will be found in the following list.

The types, unless otherwise stated, are in my Herbarium.

The figures are drawn from the type-specimens unless otherwise described.

In order to economise space and to prevent repetition I have employed the following abbreviations:

H. A. W., collected by Prof. H. A. Wager.

Sim, collected by Mr. T. R. Sim.

Hend., collected by Rev. Jas. Henderson.

D. B. and M. H., or D. Hend., collected by D. B. and M. Henderson (or Donald Henderson).

C.P. for Cape Province.

SPHAGNACEAE.

Sphagnum Pappeanum C. M. George, C.P., 1916; coll. H. A. W. (no. 568), c. fr.

S. coronatum C. M. Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (No. 311). Blinkwater Ravine, Table Mt., C.P., 1915; coll. H. A. W. (No. 591).

S. oxycladum Warnst. Zululand, 1916; coll. H. A. W. (No. 201).

S. oligodon Rehm. Kaapsche Hoop, 1915; coll. H. A. W. (No. 319). Near Hogsback, 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 225).

S. capense Hornsch. Table Mt.; coll. F. Webster, comm. G. Webster (No. 353).

var. *multiporosum* Warnst. George, C.P., 1916; coll. H. A. W. (No. 511). This agrees very well with Wilms' No. 2629, and other authenticated specimens; Warnstorf describes the var. as "Folia caulina et ramulina utrinque multiporosa."

DICRANACEAE.

Trematodon intermedius Welw. & Duby. Moorddrift, Waterberg District, Transvaal, 1915; coll. H. A. W. (No. 411), c. fr.

According to Roth ('Aussereuropaischen Laubm.', i, 258), this species has the neck of the capsule from $1\frac{1}{2}$ to 2cc the length of the sporangium. In the original specimens from Angola, however, at the British Museum, I find the neck only about equal to the capsule or a shade longer, except where the over-mature capsule has widened and shortened, when the neck is appreciably longer, but not much so. In all respects Wager's specimens agree with this plant, hitherto only recorded from tropical Africa.

Trematodon pallidens C. M. Woodbush, Transvaal; coll. H. A. W. (No. 273), c. fr. Sent to me for description as "*Trem. transvaaliensis* Wag. & Broth., n. sp., Broth. MS. in litt." I cannot separate it, however, in any way from *T. pallidens*. The teeth are not particularly pale, but that is not a character insisted on in the description of the original plant. It agrees in all other respects. The leaf margin is frequently or usually very narrowly recurved above—a character which, I think, being unusual in the genus, goes far to confirm the identification with *T. pallidens*.

Ditrichum strictum (H. f. & Wils.) Hampe (syn. *D. australe* [H. f. & W.] Mitt.). Giant's Castle, 8000 ft., Natal, 1915; coll. R. E. Symons, comm. Sim (No. 8537a). For the distribution of this species, new to S. Africa, see note below on *Aongstroemia julacea*.

Ditrichum amoenum Thw. & Mitt. Kaapsche Hoop, 1915; coll. H. A. W. (Nos. 302, 330); George, C.P., 1916; coll. H. A. W. (Nos. 514, 565); near Hogsback, 4-6000 ft., Tjume, C.P., coll. Hend. (No. 212); all c. fr.

These all agree with the Indian plant, which differs from *D. flexifolium* (Hook.) solely in having the peristome very short and rudimentary. Since *D. amoenum* is found only in collocation with *D. flexifolium*, in India and South Africa, and since the two agree in every other respect, I think there can be little doubt that this plant is but a variety of *D. flexifolium* with depauperate peristome.

Ditrichum spirale Dixon sp. nov. (Pl. XI, fig. 1.)

D. flexicauli (Schleich.) affine. Dioicum. Robustum, elatum; ad 7 cm. altum, superne olivaceum, inferne castaneum; caules dense coespitosi, viz. radiculosi, flexuosi, hic illic divisi. Folia ad 5 mm. longa, suberecta vel leniter homomalla, siccitate haud crispata, subula autem in se longe regulariter spiraliter torquata; e basi subvaginante cito in subulam duplo longiorem angustissime loriformem, sat robustam opacam attenuata, apicem versus hic illic dentibus perpaucis argutis praedita. Cellulae basillares elongatae, lineares, marginales angustissimae, tenuissimae, hyalinae, supra sensim breviores, ellipticae, subula minutae, breviter rectangulares, perobscurae. Costa ad basin lata, male definita, supra maximam partem subulae occupans. Cetera ignota.

Hab.—Gaika's Kop, alt. 6000 ft., Tjumie, C.P., 1916; coll. D. B. & M. Hend. (No. 232).

The regular corkscrew-like twisting of the subula when dry, the leaves being otherwise unaltered in position, is a marked character, best observed by holding the plant up to the light. It is somewhat similar to but rather less marked than what obtains in some species of *Syrrophodon*, e.g. *S. spiralis* Ren. & Card., *S. apertifolius* Besch. This twisting occurs very occasionally in the long-leaved forms of the northern *D. flexicaule*, but it is less easily observed there owing to the exceedingly delicate, filiform subula, which here is of an appreciable width. The rather coarse toothing of the apex and the elongate basal cells with a narrow border of very delicate hyaline ones are also distinguishing characters.

Saelania glaucescens (Hedw.) Broth. Giant's Castle, 8000 ft., Natal, 1915; coll. R. E. Symons, comm. Sim. (No. 8681). Wager ('Check-list of Mosses of South Africa,' Pretoria, 1917) records this also from Van Reenen. It is quite a recent discovery from South Africa. Distrib.: Northern Europe and Asia to Spitzbergen; Japan, Kashmir, Caucasus; North America from Greenland to Vermont and Minnesota; New Zealand.

Aongstroemia vulcanica C. M. On the ground near water, Maritzburg, 1908; coll. H. A. W. (No. 290), ♂ plant.

A. julacea (Hook.) Mitt. Giant's Castle, 8000 ft., Natal; coll. Sim. (No. 8537b).

With *Ditrichum strictum*, together with which it was growing, this constitutes a most interesting addition to the African moss-flora. The two form a further link in the curious chain of mosses having a very definite while very restricted geographical distribution, viz. southern (or high alpine) South America, South Africa, and New Zealand. They are found in either markedly high southern latitudes or at high altitudes, and seem to imply an early distribution from a common antarctic or subantarctic centre. The distribution of the two as hitherto recorded is—

Ditrichum strictum, Chimborazo, Fuegia, Falkland Is., Kerguelen, Marion Is., Auckland Is., Campbell Is., New Zealand, Tasmania.

Aongstroemia julacea, Andes of New Granada and Quito.

A. julacea is a very striking plant in appearance; the almost orbicular leaves, which are curiously cristate-papillose round the upper margin, are very closely appressed to the stems, which are quite terete and julaceous, and the plant may easily be mistaken for an *Anomobryum*.

Microdus minutus (Hampe) Besch. Moorddrift, Waterberg District, Transvaal, 1916; coll. H. A. W. (Nos. 402, 410), c. fr.; Maritzburg, 2000 ft., June, 1917; coll. Sim (No. 8711), c. fr.

No. 402 represents a small reduced form, which, however, intergrades with No. 410; the latter corresponds with *M. limosus* Besch., which, however, from a study of Bescherelle's specimens I should certainly refer to

M. minutus. I think in all probability all these will have to be reduced ultimately to *M. pallidisetus* (C. M.), of which, unfortunately, specimens have not been available.

Dicranella subsubulata (Hampe) Jaeg. Hilton Road, 3500 ft., June, 1917; coll. Sim (Nos. 8110, 8712), c. fr.

Compared with Hampe's type at the British Museum.

Dicranella Symonsii Dixon sp. nov. (Pl. XI, fig. 2.)

Elata; caules graciles, 5-6 cm. alti, parce divisi, superne ochraceo-virides, inferne sordide fuscii, parce radiculosi. Folia laxissime disposita, undique patentia, e basi amplexicauli erecta appressa, subquadrata, subito in subulam horizontaliter patentem ligulato-lanceolatam canaliculatam, subobtusam contracta; marginibus erectis, integris, costa ad basin circa 70 μ lata, superne perindistincta, infra apicem percarinatum evanescens. Cellulae basilares rectangulares, irregulariter plusminusve elongatae, flavidae, inanes, parietibus firmis; superiores omnes breviter rectangulares, parietibus transversalibus crassiusculis valde protuberantibus, unde subula ubique minute rugoso-tuberculosa. Cetera ignota. Dioica videtur.

Hab.—On wet stones, Giant's Castle, alt. 7000 ft., Natal, 1915; coll. R. E. Symons, comm. Sim (No. 8665).

A very distinct species from those hitherto recorded from Africa, and showing a connection with a certain Australasian and subantarctic group, including *D. clathrata* H. f. & W., *D. vaginata* (Hook.), etc., which for the most part have smooth cells. A New Zealand species, *D. wairarapensis* Dixon, is still nearer it in the papillose subula, but is very different in habit and other respects.

Campylopus nano-tenax (C. M.) Par. Woodbush, Transvaal, 1914; coll. H. A. W. (Nos. 56, 130), c. fr.; Knysna, coll. H. A. W. (No. 507), c. fr.; George, C.P.; coll. H. A. W. (No. 542b), c. fr.

The different gatherings show some distinctions in length and serration of subula, in width of base and of nerve, etc., but they are not constant, even in leaves from the same stem, and they must all be referred to the same species. I am not able to distinguish any difference in the vegetative characters from *C. Goughii* (Mitt.) from India, and the resemblance is heightened by a rather unusual peculiarity in the capsule, which here as well as in the Indian plant may occasionally be very turgid, glossy, and almost entirely without striae. The distribution of the two plants does not at all support their identity, and I have not ventured to do more than suggest the possibility, but I would draw the attention of bryologists to the question.

Campylopus trichodes Lor. Cape Town, on granite rocks, 1906; coll. H. Nicholson; ditto, coll. H. A. W. (No. 365); Table Mt., 1910; coll. H. A. W. (No. 13c); bed of Tugela R., among rocks, 6000 ft., Natal, 1915, coll. Dr. Bews, comm. Sim (No. 8374); top of Zwaart-kop, 5000 ft., Natal,

1917; coll. Sim (No. 8699); Giant's Castle, 8000 ft., Natal, 1915; coll. Sim (No. 8691). All sterile.

What I take to be Lorentz' species varies very considerably in degree of robustness, but the forms agree with one another in leaf-structure; the nerve is strongly lamellate at back, the leaves erect when dry so that the stems are penicillate, with more or less conspicuous hyaline points which are erect, not at all reflexed. No. 13c is one of the smaller forms with less developed hair-point, and agrees very well with Rehmann's *M. Austr.-Afr.* No. 56.

C. purpureo-aureus (C. M.) Par. Natal, coll. H. A. W. (No. 232); Giant's Castle, 8000 ft., Natal, 1915; and near top of Zwaart-kop, 5000 ft., Natal, June, 1917; coll. Sim (Nos. 8690, 8700). Both the latter are elongate, slender forms, but structurally they present no difference.

C. introflexus (Hedw.) Mitt. Giant's Castle, 8000 ft., Natal, 1915; coll. R. E. Symons, comm. Sim (No. 8689). A slender form, which is probably *C. lepidophyllus* C. M., but I find nothing to separate it from *C. introflexus*; similar forms are not infrequent in New Zealand.

C. leucobasis (C. M.) Par. Muizenberg Mts., Kalk Bay, 1500 ft., C.P., 1900; coll. C. H. Hobkirk, comm. G. Webster (No. 919); near Cape Town, 1915; coll. H. A. W. (No. 344); Montagu Pass, C.P., 1916; coll. H. A. W. (No. 567p.p.), c. fr.

No. 919 has rather narrower supra-basal cells than in *C. Mueller's* plant and the subula is rather rougher, but I do not think the differences are of any importance. The other two plants are more exactly identical. The plant is to all intents and purposes, however, a form of *C. introflexus*, with the back of the nerve smooth and not lamellate, and I doubt if it be really different from *C. pudicus* (Hornsch.).

C. bicolor (Hornsch.) Jaeg. Cape of Good Hope, 1912, coll. S. W. Hall (Nos. 4, 5, 9). This species, hitherto known from Australia only, must, I think, now be credited to S. Africa. The plants in question form three separate gatherings, one of them decidedly more slender; all, however, agree in the structure of the leaf with the Australian plant, which is especially marked by the abruptly obtuse, cucullate apex of the leaf. In this it differs therefore from the *C. pseudo-bicolor* C. M. of Madagascar, which has a shortly pointed leaf. Like the Australian species also, the Cape plant, while showing obtuse, mucous leaves nearly throughout the stem, has a distinct short hyaline point on the floral leaves, and occasionally the comal leaves of sterile branches are acute or shortly hyaline-tipped. For this reason, supplemented by certain others drawn from Australian specimens, I have elsewhere given my opinion that the obtuse, cucullate apex of *C. bicolor* is to be considered rather as an abnormal or varietal character than as a natural and specific one (cf. the British var. *muticus* of *C. atrovirens*). In that case it is probable that *C. pseudo-bicolor* is really conspecific with the Cape plant.

C. inchangae (C. M.) Par. Buccleuch, 4000 ft., Natal, 1912; coll. Sim (No. 8544) c. fr.; Kaapsche Hoop, Transvaal, coll. H. A. W. (Nos. 209, 300) c. fr.; Montagu Pass, C.P.; coll. H. A. W. (No. 567 p.p.).

Sim's plant agrees exactly with Rehmann, M. Austr.-Afr. 42. Wager's plants are a little smaller, but agree structurally. The fruiting plant is, as often, rather less robust than the sterile ones. C. Mueller's description (Hedwig, 38, p. 83) is decidedly misleading; the description of the stem-leaves as "minuta" is absurd, while that of the lamina as "summitate denticulato-abruptam" is quite inaccurate, as the subula (in Rehmann's plant) is sharply denticulate for some way down, both on the back and the margins. The perichaetia are aggregate, the capsules rather large, the calyptra deeply fringed at base.

The species appears to be a highly variable one; the nerve varies greatly in width from one-third to three-fifths of the width of the leaf, or more; the subula may be rather short and stout or longly filiform, especially in the floral leaves, while the auricles, always well developed and generally of a beautiful orange-brown, may be much dilated or scarcely wider than the leaf-base. The species is very near indeed to *C. purpureo-aureus* (C. M.), and the two will, I believe, have to be united ultimately. The leaves are, in the more robust forms especially, very hygrometric, as in that species.

This species has given rise to a good deal of doubt as to the proper spelling of the specific name. The name as printed in Hedwigia, as above cited, is "*Dicranum Inerangae* Rehm. in Musc. A. Afr. No. 42," and the locality is given as "Natal, Ineranga." Now there is no such locality known; nor is it a correct transcription of Rehmann's label, which appears to be undoubtedly *Inczanga*. (Paris, it may be remarked, has it in Ed. I as *Inerangae*, which in Ed. II he corrects to *Imerangae*, making matters rather worse!)

The point appears to be governed by Art. 57 of the Vienna Rules: "The original spelling of a name must be retained, except in the case of a typographic or orthographic error." It is clear that C. Mueller's *Inerangae* falls under the first heading, since he definitely cites Rehmann's MS. name, which is certainly *not* *Inerangae*; it would clearly therefore be justifiable to change it to *Inczanga*. This, however, would seem further to involve an "orthographic" error. The spelling *Inczanga* does not correspond to any recognised spelling of the locality, but is apparently Rehmann's transcription of the native name as it sounded to his ears. The native name has now become thoroughly fixed and permanent, and has been, as Mr. Sim informs me, for thirty years one of the best known railway-stations in Natal, as *Inchanga* (pronounced Inchānga). It appears to me best, therefore, to adopt this spelling.

Microcampylopus nanus (C. M.) C. M. George, C.P., and Cape Town, 1916; coll. H. A. W. (Nos. 538, 559), c. fr. I found some difficulty in deciding whether these plants should be attributed to *M. nanus* or to

M. pusillus (Schimp.) C. M., which, according to C. Mueller's diagnosis, chiefly differs in the straight, not cygneous seta—"strictiusculo nec campylopodiaceo"; here it is flexuose when young, erect and straight when old. In Wager's plants, too, the leaves are very long and flexuose, while C. Mueller describes those of *M. nanus* as "brevia, firma, parum secunda stricta," and those of *M. pusillus* as "remota, eleganter flexuosa." But this distinction is not borne out at all by the specimens, as Rehmann's No. 34—on which *M. nanus* is founded—has the leaves very flexuose and elongate. The present gatherings on the whole are indeed intermediate between C. Mueller's description and the actual type! I have therefore no hesitation in referring them to *M. nanus*, but I am almost equally convinced that *M. pusillus* is the same thing—a point, however, which I am unable to clear up, as there are unfortunately no specimens of *M. pusillus* in Schimper's herbarium at Kew. In any case the name *M. nanus* has the priority, as *Campylopus pusillus* is an unpublished name.

Dicranodontium chlorotrichum (C. M.) Par. Near Hogsback, 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 196).

Dicranodontium perfalcatum (C. M.) Par. Hogsback, Tjumie, C.P., 1917; coll. D. Hend. (No. 349).

LEUCOBRYACEAE.

Leucobryum madagassum Besch. Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (No. 337).

This species has not been recorded from continental Africa, so far as I am aware. It differs from *L. Gueinzii* C. M. notably in the chlorocysts in nerve-section being distinctly hypercentric in the upper part of the leaf. The foliation is rigid and somewhat regularly seriate, whence the name *L. selaginelloides* applied by C. Mueller to the species ('Journ. Bot.' 1888, p. 264).

FISSIDENTACEAE.

Fissidens rufescens Hornsch. Cape Town, 1916; coll. H. A. W. (No. 585), c. fr.; Cape of Good Hope, coll. F. Webster, comm. G. Webster (No. 986). Apart from the reddish colour, which is not always present, this species is notable in the form and direction of the leaves, which are not complanate and closely vaginant as usual, but have the vaginant lamina open, one wing being much larger than the other; the dorsal lamina is often—especially in the lower leaves—very little developed. The hyaline border is frequently intramarginal near base.

F. cuspidatus C. M. George, C.P., 1916; coll. H. A. W. (No. 548) c. fr. This species is heteroicous. The fertile flower may be apical, or terminal on a very short basal branch. The ♂ flowers are principally

lateral, either on a fertile stem or on a separate stem (which, however, might develop ultimately a terminal ♀ flower); they are also occasionally basal. They are rather large and numerous. The leaf-cells are unusually elongate and rather large, with thin walls.

F. pycnophyllus C. M. Mr. Sim records this from Nottingham Road, Natal, 1917; coll. Dr. P. van der Bijl (No. 8647).

Fissidens papillifolius Dixon, sp. nov. (Pl. XI, fig. 3.)

§ SEMILIMBIDIUM. Autoicus. Flores masculi foliorum axillis siti. Pusillus, viridissimus; folia plurijuga, haud nitida, madida complanata, frondem circa 1.5 mm. latam instrumentia., sicca fortiter incurvo-falcata; oblonga, haud acuminata, acuta vel subobtusata et apiculata. Costa sat angusta, pellucida, percurrentes vel brevissime excurrentes. Lamina dorsalis ad basin costae sat abrupte desinens; lamina vaginans tantum optime, late (praecipue in foliis caulis fertilibus) limbata, ceterum marginibus valde regulariter crenulatis. Cellulae distinctae, opacae, perchlorophyllosae, 5-6 μ latae, hexagono-rotundae, utraque pagina altissime spiculoso-papillosoe. Seta 3 mm. longa, theca erecta, minuta, elliptica, leptodermica.

Hab.—Walls, Umgeni Nook, Albert Falls, Natal, alt. 2000 ft., 1917; coll. Sim (No. 8709), c. fr. pauc.

A distinct species, differing markedly from most of the African species of this section in the small size, the leaves broadly pointed and not at all acuminate, the highly crenulate margin, and especially the cells, which are not obscure as in most of the species, but well defined, although opaque, and are very strikingly papillose, the papillae being dense, highly elevated and spiculose, usually in fact exceeding in height the diameter of the individual cell.

F. Borgenii Hampe.

Nov. var. *obtusifolius* Broth. MS. in litt. Folia rotundato-obtusata; costa longe infra apicem evanida.

Hab.—"Van Reenen and Pretoria" (H. A. W. in sched.); Van Reenen, No. 166.

In the type the leaves are acute, variously pointed, with the nerve mostly percurrent.

F. subobtusatus C. M. Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (No. 315). There is sometimes the faintest possible trace of border on the vaginant lamina, but it is practically negligible.

F. pseudo-serratus (C. M.) Jaeg. Hogsback, Tjumie, C.P., 1917; coll. D. Hend. (No. 338), c. fr.

F. amblyophyllus C. M. Kaapsche Hoop, Transvaal, 1915, and Knysna Forest, C.P.; coll. H. A. W. (Nos. 327, 10); near Hogsback, 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (Nos. 215, 198). The latter is so much larger a plant than the other gatherings that it would seem likely to be *F. procerior* Broth. & Bryhn; but the apex and dorsal lamina (here decurrent)

agree much better with the description of *C. Mueller's* plant. I think in all probability they may both be forms of one and the same species. It may be noted that in this plant the form in which the dorsal lamina terminates below is not as in many or most species a reliable character. On the same fertile stem I have seen all stages between an abruptly rounded, auricle-like ending and the most gradual narrowing or decurrence.

F. glaucescens Hornsch. Rietfontein; and Barberton, Transvaal, 1914; coll. H. A. W. (Nos. 283, 255a), c. fr.; Table Mt., 1896; coll. W. A. Walker; Zululand, comm. G. Webster (No. 984).

F. plumosus Hornsch. Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (No. 317); Knysna, C.P.; and Blinkwater ravine, C.P., 1916; coll. H. A. W. (Nos. 504, 589).

No. 317 differs from the type-form in the leaves being rather narrower, with more finely acute, more serrulate points, but the differences are not of importance. The other two numbers are the normal plant.

F. cymatophyllus C. M. Near Hogsback, 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 192). Does this really differ, I wonder, from *F. glaucescens*?

F. julianus (Sav.) Schimper. In water, Maritzburg, 1906; coll. H. A. W. In water, Gwacwalia R., King William's Town, C.P., 1892; coll. Sim (No. 7096); streams in Pirie Forest, C.P., 1892 and 1893; coll. Sim (No. 7118), c. fr.

It may be worth while to go somewhat fully into the history of this plant and the reasons for referring it to the northern species. *C. Mueller* (Syn. i, 44, 45) separates *F. Berteri* C. M. from *F. julianus* as having "fructus in ramo brevissimo" in contrast to the "fr. in ramo longiusculo" of the latter species. *F. Berteri* is described as fruiting, and two plants are attributed to it—Bertero's from Chile and Drege's from the Cape of Good Hope. A note expresses doubt whether it is sufficiently different from *F. Dillenii* C. M. In the same work (ii, 525), under *Conomitrium*, *C. Mueller* separates the South African plant from the South American one as *C. capense*, citing the same plants of Drege and adding "sterile tantum notum." He describes it as "*C. Berteri* simillimum, sed caules longissimi, apice gemmaceo-folioso incrassato falcato praediti." This character, however—which on the face of it does not appear of any great value—is not shown on any of the Cape plants I have seen.

So far, therefore, there is nothing to indicate any difference between the Cape plant and the northern *F. julianus*. On the other hand, vegetatively it agrees equally well with *F. Dillenii* C. M.; and if this is really separable from *F. julianus* on the ground of the position of the fruit, it would be reasonable to assume in the absence of fruit that the Cape plant was probably the same as the S. American species, not identical with the northern plant; and therefore to be known as *F. Dillenii*. Fortunately, however, Mr. Sim has collected the plant in very nice fruiting condition,

and it is possible, therefore, to determine its true position and relationships.

The capsules are numerous, frequently produced in each leaf axil for a considerable portion of the stem; the seta is uniformly about 1 mm. long; the perichaetia are very short, so that they may be considered truly axillary (not terminal on an axillary branch); the bracts vary considerably in length, sometimes very little exceeding the vaginula, sometimes much longer, and reaching to or beyond the capsule. The fruit would therefore undoubtedly come under C. Mueller's head "fructus in ramo brevissimo," and if this character be of any value the Cape plant must be referred to *F. Dillenii* C. M. and kept separate from *F. julianus*. What, then, is the value of this character? It is discounted, surely, at the beginning by the fact that both forms of inflorescence are attributed to *F. julianus* by the authors of the 'Bryologia Europaea,' who distinctly state "flos femineus in ramis nunc elongatis et frondiformibus, nunc abbreviatis et microphyllis terminalis," and these two forms are actually figured (Tab. 108, figs. 7, 12). This would surely be sufficient to negative the value of the character, but as it might be suggested that the authors had confused two species, I have examined as many fruiting specimens as possible and the result has been entirely to confirm the statement of the 'Bryologia Europaea.' Among the northern specimens of *F. julianus* at Kew I find on the rare fruiting specimens most of the capsules having the very short, almost leafless perichaetia, but a few show the elongate, foliose axillary branchlets with terminal capsules. For the most part these occur on separate plants, but in at least one plant of Drummond's (doubtless a North American specimen) there are numerous capsules of the first kind, and one at any rate borne on the elongate foliose branchlet upon the same plant.

Precisely the same thing occurs in a specimen in my herbarium of *F. mollis* (C. M.) Broth., from Monte Video, coll. Gibert; on one and the same stem there are many of the elongate foliose ramuli bearing terminal capsules and several of the axillary, "sessile" perichaetia. Clearly, therefore, the value of the character as a specific difference disappears, and there is nothing to separate the southern plant, which has been described as *F. Berterii* C. M. and *F. Dillenii* C. M. in Chile, etc., *F. capensis* C. M. in S. Africa, and *F. Muelleri* Hampe in Australasia, from the widely distributed *F. julianus*.

CALYMPERACEAE.

Syrrhopodon obliquirostris C. M. Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (No. 288), c. fr. Agrees well with specimens in the British Museum collection.

S. uncinifolius C. M. Near Hogsback, alt. 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 197). This appears to agree, in its differences from

S. obliquirostris, with the description given by C. Mueller (stems scarcely clavate, leaves longer, more spirally twisted, more acute and more spiculate at apex); only the leaves do not seem to be "introrsam uncinata" when moist. Rehm. M. Austr.-Afr. 486, however, agrees quite well, and it is clear from this specimen that the above character does not refer to the general direction of the leaves, but only to the inflexed apex.

S. pomiformis (Hook.) Hampe. I have had this sent from two or three collectors at the Cape of Good Hope, but only one from any other locality, viz. Muizenberg Mt., near Kalk Bay, July, 1900; coll. C. H. Hobkirk, comm. G. Webster (No. 499).

POTTIACEAE.

Gymnostomum Bewsii Sim MS. in sched. (Pl. XI, fig. 4.)

Autoicum; flos ♂ prope fl. ♀ situs. Dense coespitosum, 1-3 cm. altum, superne viride, inferne fuscum vel pallide ochraceum; caules gracillimi, fragiles, saepe interrupte foliosi; folia sat conferta, patentia vel paullo recurva, sicca crispula, parva, 1-1.5 mm. longa, e basi parum latiore ligulata, obtusa vel subacuta, saepius cellula singula hyalina apiculata; concavo-carinata, marginibus planis, integris; costa basi latiuscula, supra obscura, dorso plerumque valde muriculata. Cellulae basilares hyalinae, breviter rectangulares (circa 2 × 1); superiores chlorophyllosae, irregulariter quadratae, minute papillosae, 6-8 μ latae, marginales superne saepe seriebus duabus bistratosae. Seta 3-5 mm. alta, flavo-rubella; theca parva, elliptica, gymnostoma, collo brevi, distincto, maturitate pallide aurantiaca, ore rubro, operculo tenuirostrato, obliquo; exothecii rete collenchymaticum, e cellulis elongatis instructum, ad orificium seriebus circa quinque, minoribus, isodiametricis, parietibus crassioribus, saturate aurantiacis; annulus haud evolutus. Spori 10-13 μ , punctulati. *Hymenium nullum*.

Hab.—East Griqualand, Mar., 1915; coll. Bro. Mayol, comm. Sim (No. 8251); Tugela Gorge, 6000 ft., Natal, Sept., 1915; coll. Prof. Bews, comm. Sim (No. 8660); on face of rock, Goodoo Pass, Drakensberg, Natal, alt. 7000 ft., 1915; coll. Prof. Bews, comm. Sim (No. 8713); Upper Bushman's River, Natal, alt. 7000 ft., Sept., 1905; coll. Sim (No. 8658); Giant's Castle, Natal, alt. 7000 ft., 1915; coll. R. E. Symons, comm. Sim (No. 8661); Rydal Mt., coll. H. A. W. (No. 97); Van Reenen Pass, Natal, coll. H. A. W. (No. 7).

Evidently a frequent plant, and somewhat variable, but not difficult to recognise from the yellowish, gymnostomous capsules, the narrow, plane-margined leaves, carinate with the somewhat prominent nerve, which is usually, but not always muriculate at back, and the bistratose marginal cells.

Its generic position is not quite certain. The bistratose cells are almost unique among these small gymnostomous Trichostomoid mosses;

the autoicous inflorescence is rare, if not unknown in *Gymnostomum*. On the other hand the entire absence of hymenium precludes *Hymenostomum*, of which also it has not the habit; and it seems most at home here; it is not indeed unlike some forms of *G. calcareum* in appearance and fruit.

Gymnostomum gracile (Wager) (*Weisia gracilis* Wager in 'Trans. Roy. Soc. S. Africa,' iv, p. 4) is nearly allied, but has wider, more obtuse leaves, nerve more highly scabrous at back, seta distinctly longer, etc.

Wager's Pretoria plant (No. 97) had been submitted to Dr. Brotherus, and was determined by him as "*Eucladium* (or *Weisia*) *africanum* Wag. & Broth., sp. n." It is identical with Sim's plant, however. Brotherus' determination attests the doubt as to the generic position of the species. The entire absence of peristome appears to me on the whole to preclude *Eucladium* as well as *Weisia*.

Trichostomum cylindricum (Bruch) C. M. Near Hogsback, 4600 ft., Tjumie, C.P., 1916; coll. Hend. (No. 202), c. fr.; and again, 1917, coll. D. Hend. (No. 328p.p.).

This species has not been recorded from continental Africa. It appears to be a more widely-spread plant than has been recognised; it is known from the greater part of Europe and N. America, from Sikkim to Ceylon in Asia, and from the Andes in S. America. Cardot has recorded it (M. de Madagascar) from two localities in Madagascar, where it is sterile. The fruit of No. 202 shows scarcely any difference from the European plant; the seta is a shade stouter and redder, and the capsule a little more pachydermatous, but even these characters are not constant. The peristome agrees well.

Trichostomum brachydontium Bruch. Near Hogsback, 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 194); Zululand, comm. G. Webster (No. 927); Camperdown, Natal, 2000 ft., 1900; coll. H. M. Pearson, comm. G. Webster (No. 926).

This species has been recorded from Reunion, and is well known from the West African Islands, but has not yet been published from continental Africa, I believe. It is sterile only in the above gatherings, but I cannot separate it vegetatively from our European plant.

Tortella rufiseta (C. M.) Broth. George, C.P., 1916; coll. H. A. W. (No. 505), c. fr.; Knysna, C.P., 1916; coll. H. A. W. (No. 528), c. fr.

The cells in this species are unusually clear and pellucid. C. Mueller describes the peristome as red, and I find the short basal membrane red, and the teeth reddish when seen with the lens, but by transmitted light the teeth are orange or yellowish; they are marked by delicate and rather striking spirally arranged papillae.

Tortella xanthocarpa (Schimp.) Broth. George, C.P., 1916; coll. H. A. W. (No. 505b), c. fr. Mixed with *T. rufiseta*, and resembling it in appearance, but quite distinct in the autoicous inflorescence, short seta,

obscure cells and decidedly twisted peristome. The teeth in *T. rufiseta* are only very slightly twisted, in the negative direction.

Tortella tortuloides (Sull. & Lesq.) Broth. Barberton, 3000 ft., Transvaal, 1917; coll. Sim (No. 8684).

Trichostomum sulphureum Rehm., M. Austr. Afr. 471, appears to me to be a small state of this species. Paris' reference of this to *Leptodontium*, as *L. transvaaliense* Par., is due to some confusion merely; *Trichostomum sulphureum* Rehm. is ante-dated by *T. sulphureum* C. M. (*Leptodontium sulfureum* Mitt.), and this no doubt led to the confusion on the part of Paris; Rehm's plant could under no circumstances be considered a *Leptodontium*. Rehm's name is moreover a *nomen nudum* only, and as it seems to me almost certainly the same thing as the present species, I think the name may very well be allowed to disappear.

Triquetrella strictissima (Rehm.) C. M. Near Cape Town, 1915; coll. H. A. W. (No. 345). Alicedale, C.P., 1912; coll. Prof. G. Potts, comm. Sim. Mr. Sim sent the last as *T. tristicha* C. M., remarking that he could not separate Rehm's *Zygodon strictissimus* from it. The two seem to me doubtfully distinct; Rehm's specimen of *T. tristicha* has short, closely imbricate leaves and strongly triquetrous stems, and if these characters be of any value I think Prof. Potts' gathering must be referred to *T. strictissima*.

? *Triquetrella filicaulis* Dus. Near Hogsback, 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 187a). A few stems picked out of *Thuidium promontorii*. A very different plant from the above, with elongate, flexuose stems, 4-5 cm. long, very sparsely branched, with distant leaves, which are widely spreading to squarrose, and strongly decurrent at base, and especially marked by having the stems finely muriculate throughout. In all these characters it agrees with *T. filicaulis* Dus. from Southern Chile, original specimens of which I have compared. That species, however, is compared by Dusen with *T. scabra* C. M. from Victoria, Australia, from which he says it can hardly be separated vegetatively, but the peristome characters appear to afford some specific differences. In the absence of fruit it appears to me impossible to say with certainty to which of these two species, if either, the African plant is to be referred. The muriculate stem is a sufficiently unusual character to justify a strong presumption in favour of *T. filicaulis*, but I have not been able to examine specimens of *T. scabra* to see if it obtains there also. Dusen in his description of *T. filicaulis* does not mention this character; he also describes the leaves as "vix decurrentia," but I find them markedly decurrent in his specimens, and the stems are muriculate as in the African plant.

Leptodontium squarrosus (Hook.) Par. (syn. *L. epunctatum* [C. M.] Par.). Woodbush, Northern Transvaal, 1910; coll. T. Jenkins, comm. W. Ingham,

c. fr.; Rosehaugh, 4000 ft., Transvaal, Dec., 1914; coll. Sim (No. 8540); Maritzburg, 4000 ft., 1917; coll. Sim (No. 8705), c. fr. This last locality, Mr. Sim remarks, is several hundred miles further south than it was previously known.

Cardot, in the 'Mousses de Madagascar,' has given strong reasons for uniting the African plant with the Indian *L. squarrosus*. He also points out the variability of the plant, and in view of this I should have no hesitation in referring Rehmann's *L. armatum* to the same species; *L. armatum* Rehm., M. Austr.-Afr., No. 46, would be *L. squarrosus* var. *paludosus* (Ren. & Card.) Card., while *L. armatum* var. *brevifolium*, Rehm., No. 467, would be ordinary *L. squarrosus*, in my opinion.

Hyophila atrovirens (Rehm.) Broth. Zwaartkop Valley, Maritzburg, on wet stones in stream, 2500 ft., June, 1917; coll. Sim (No. 8685). The plant, Mr. Sim notes, is always saturated, often submerged, and is abundant in some of the Natal streams, but not fertile. A single capsule of Rehm., M. Austr.-Afr., No. 475 (not 495 as cited by Paris), showed a distinct annulus. Rehm., No. 121, *Trichostomum riparium*, contains a mixture of this plant sterile, with fruiting *Glyphomitrium cucullatifolium*.

H. Zeyheri (Hampe) Jaeg. Hogsbak, Tjume, C.P., 1917; coll. D. Hend. (No. 352a). Maritzburg, 2000 ft., 1916; coll. Sim (No. 8253), c. fr. Also, as *Hymenostomum opacum* Wager, from dry banks, Pretoria, 1910, and Barberton, Transvaal, 1914-5; coll. H. A. W. (Nos. 20, 278), c. fr. Further, as "*Hymenostomum* (or ? *Weisia*) *hyophiloides* Wager & Broth., sp. n.," from Pretoria, coll. H. A. W. (No. "222 or 240"), c. fr.

I find on careful comparison that there is nothing to separate these last two plants from *Hyophila Zeyheri*, which appears to be a little-known species, and, as Brotherus points out, of somewhat doubtful position. The vegetative characters are those of *Hyophila*, while the short, oval capsule, which may have the mouth closed on deoperculation with a membrane, suggests *Hymenostomum*.

Didymodon Pottsii Dixon, sp. nov. (Pl. XI, fig. 5.)

Dense coespitosus, superne saturate olivaceus, inferne pallide fuscus; caules circa 1 cm. alti, parce divisi, graciles; folia laxiuscula, apice subcomosa, breviter, 1 mm. longa, patula, sicca erecta subappressa, haud torquata, e basi latiore subdecurrente late lanceolato-lingulata, apice rotundato, subacuto, seu rarius obtuso, marginibus angustissime reflexis; costa latiuscula, per totam longitudinem subaequalis, nec supra angustata, carinata, infra apicem soluta, dorso ubique scaberrima. Cellulae chlorophyllosae, aetate inanes pellucidae, hexagonae vel subrotundo-quadratae, parietibus tenuibus, circa 8 μ latae, tenuiter papillosae; basillares parum majores, haud elongatae, subquadratae.

Diocis. Folia perichaetialia majuscula, intima breviter obtusa. Setae 75-1 cm. longa, rubra; theca breviter elliptica, castanea, nitens, operculo rostello cellulis seriebus subrectis dispositis. Peristomium nullum. Exo-

theeii rete firmum, cellulis orificium versus sensim minoribus, subincrassatis. Spori 16–20 μ , laeves.

Hab.—Eagle's Nest, Bloemfontein, Dec., 1916; coll. Prof. Potts, comm. Sim (No. 8663).

This appears from the foliage to belong to *Didymodon* (subgenus *Didymodon sensu stricto*, Limpr.), and being gymnostomous is allied to *D. afer* C.M., but differs widely from that species, *inter alia* in the leaf apex, which while little narrowed is usually acute or subacute, rarely rounded. It many respects it resembles very closely the smaller forms of the European *D. tophaceus* (Brid.), which, however, is peristomate and has not the scabrous nerve of the present species.

Didymodon afro-rubellus Broth. & Wager (Broth. MS. in litt. ad H. A. Wager). (Pl. XI, fig. 6.)

Subgenus *ERYTHROPHYLLUM* Limpr. Habitu *D. rubelli* (Hoffm.), sed *multo minor*, tenerrimus, caules vix 1 cm. alti, gracillimi, flexuosi. Folia patentia, sicca flexuoso-incurva, 1.25–1.75, rarius 2 mm. longa, e basi parum latiore late lingulata, obtusiuscula, apiculata, marginibus hic illic leniter reflexis vel subplanis, integris vel apice irregulariter obscure sinuatis; costa validiuscula, rufescens, in apiculum pallidum mucroniformem excurrent, superne dorso minute scaberula. Areolatio perdensa, opaca, e cellulis minutis, densis, rotundo-quadratis, dense minute papillosis instructa. Cellulae basilares abrupte elongatis, anguste rectangulares, seu lineares, tenues, hyalinae, marginales seriebus nonnullis minores, chlorophyllosae, limbum basin fere attingentem formantes. Seta pallide rubra, brevis, circa 5 mm. longa, tenuis, flexuosa; theca minuta elliptica, operculo conico brevi, rostellato; exothecium leptodermicum, pallidum, e cellulis breviter late rectangularibus instructum. Peristomium fragile, e dentibus brevissimis, angustissimis, rubellis, dense papillosis, basin versus in membranam brevissimam cohaerentibus.

Hab.—Van Reenen Pass, coll. H. A. W. (No. 79).

Resembles *D. rubellus* in miniature, but with wider, shorter, widely pointed obtuse leaves, which are not denticulate at summit, but at the most obscurely sinuate or notched.

Barbula pilifera Brid. Cape Town; coll. H. A. W. (No. 362 bis). Fort Murray, King William's Town, C.P., 1893; coll. Sim (No. 7323).

B. torquescens Schimp. Table Mt., coll. F. Webster, comm. G. Webster (No. 332), c. fr.

Tortula atrovirens (Smith) Lindb. In innumerable forms as regards size, shape of leaves, size of cells, development of peristome, etc.; Cape Town; coll. H. A. W. (Nos. 547, 556, 557), c. fr.; Moorddrift, Waterberg District, Transvaal, 1916; coll. H. A. W. (No. 409), c. fr. *T. recurvata* Hook., albeit very distinct in appearance from the ordinary European form, is without any doubt to be referred to this species.

T. erubescens (C. M.) Broth. Zoutpansberg District, North Transvaal, 1910; coll. T. Jenkins, comm. W. Ingham. Upper Bushman River, 6000 ft., Natal, 1905; coll. Sim (No. 8669).

I have elsewhere (Smithson. Miscell. Colls. 69, 2, p. 14) given my opinion that *Barbula oranica* C. M., and *B. exesa* C. M. are inseparable from the tropical and subtropical species described by C. Mueller as *B. erubescens*.

T. erythroneura (Schimp.) Broth. Cape of Good Hope, 1912; coll. S. W. Hall. This agrees well with Schimper's specimen, coll. Wilms, at Kew. But is it anything more than a *ruralis* form?

T. princeps De Not. Near Cape Town, 1915; coll. H. A. W. (No. 350), c. fr. A synoicous plant, which I cannot separate in any way from this almost cosmopolitan species.

T. brachyaechme (C. M.) Broth. Hout Bay, C.P., 1916; coll. H. A. W. (No. 604), c. fr.; Hogsback, Tjummie, C.P., 1917; coll. D. Hend. (No. 325). This latter plant shows abundant comal propagula foliose in form, and often developing in *situ* into short leafy stems. Prof. Wager's plant has exceedingly small and short capsules, but I am unable to say to what extent this is due to depauperation.

Brotherus, as also Paris, writes the specific name *brachyaechme*; C. Mueller as *brachyaichme*. The derivation is clearly from *αἶχμη*, the correct transliteration of which would be *-aechme*.

T. Eubryum (C. M.) Dixon. Rietfontein, Transvaal, 1916; coll. H. A. W. (No. 243). See also my note in 'Bull. Torr. Bot. Club,' 43, 66.

Tortula trachyneura Dixon, sp. nov. (Pl. XI, fig. 7.)

Diocia videtur; flos femineus tantum visus. T. rurali proxima; differt costa supra dorso alle grosso sparse scabra. Folia obtusissima, marginibus peranguste hic illic reflexis, costa in aristam longam hyalinam dentatam excurrens; cellulae superiores majusculae, 10-14 μ latae, sat distinctae.

Hab.—Tjummie, C.P., 1917; coll. D. Hend. (No. 330).

This may possibly belong to *T. ruralis*, but the roughness at the back of the nerve is different from anything I have seen in that species. There it may be quite smooth or markedly but finely muriculate; here it is coarsely and sparsely papillose or almost hispidulose. None of the other South African species show this character of nerve.

Encalypta ciliata Hoffm. Wittebergen, Herschel, 8-9000 ft., C.P., 1917; coll. I. Hepburn, comm. Sim (No. 8706), c. fr.

GRIMMIACEAE.

Glyphomitrium crispatum (Hook. & Grev.) Broth. Table Mt., 1910; Cape Town, 1915; coll. H. A. W. (Nos. 31, 356), c. fr.; Van Reenen, 1914; coll. H. A. W. (No. 83), c. fr.; Platte Klip, near Cape Town, 1906; coll. H. Nicholson, c. fr.

G. cucullatifolium (C. M.) Broth. In cushions on rocks, 6-9000 ft., Wittebergen, Herschel, C.P., 1917; coll. Ivan Hepburn, comm. Sim (No. 8708), c. fr. The very short seta and short small capsule are marked features of this species.

G. depressum (C. M.) Broth. Hogsback, Tjumie, C.P., 1907; coll. D. Hend. (No. 324), c. fr. The fruiting characters are in the main the same as those of the last species; the calyptra is, however, much more longly beaked, as is also the capsule lid. The reflexed margin is also characteristic—an unusual feature in the genus.

Glyphomitrium marginatum Wager & Dixon, sp. nov. (Pl. XII, fig. 23.)

E. robustioribus. Caules ad 4 cm. alti, adscendentes, dense foliosi, coespites elatos nigro-virides efficientes. Folia erecto-patentia, e basi *brevi parum latiore* lingulato-lanceolata, breviter acuminata, subacuta, ob margines ad apicem conniventes subcucullata, concavo-carinata, marginibus *planis*, integerimis; costa sat valida, per totum fere folium subaequalis; cellulae *majusculae, pellucidae, perdistinctae*, laeves, pulchre seriatæ, apicem versus saepius *hic illic bistratosae, marginales per partem folii majorem 2-3-seriebus pluristratosae, limbum saturatius viridem* formantes. Cellulae basiales paullo *elongatae*, breviter rectangulares, parietibus firmis, subincrassatis; infimae tantum laxiores, rectangulares, pellucidae. Seta .75-1 cm. alta; theca *angusta, cylindracea*, collo distincto praedita, sicca leniter plicata. Peristomium (imperfectum) rubrum breve? Calyptra, operculum, haud visa.

Hab.—Kaapsche Hoop, 6000 ft., Transvaal, 1915; coll. H. A. W. (No. 298). Hogsback, Tjumie, 4-6000 ft., C.P., 1916; coll. J. H. (No. 190), c. fr.; and again, coll. D. Hend. (No. 352b).

This differs from *G. crispatum* at once in the narrowly cylindrical capsule, at least when dry and empty; the more robust habit and somewhat longer seta. *G. crassinervium* (Schimp.), which I have not been able to see, differs, *e descr.*, in the nerve, very wide at base and gradually tapering upwards; in the wide leaf-base with lax cells; the seta also is described as short, while it is here rather unusually long; and there is no suggestion in that of a bistratose margin.

Since the above description was drawn up, a new species of *Glyphomitrium* (or *Ptychomitrium*), collected by Prof. Wager in South Africa, has been described by Capt. Potier de la Varde, under the name of *P. subcrispatum* Thér. & Potier de la Varde ('Rev. Générale de Botanique,' xxx, 65), which I at first suspected would prove to be identical with the present plant, especially as one of the prominent features in *P. subcrispatum* is the thickening of the margin of the leaf as in this. Comparison of the two plants, however, revealed certain differences, and Capt. P. de la Varde agrees with me that the two must be kept separate. *P. subcrispatum* differs in the laxer foliage, shorter seta and smaller capsule; in *P. subcrispatum* the capsules are very frequently two in the same perichaetium, while here they

are single. The basal cells in *P. subcrispatum* are wider towards the margin, and subquadrate; here they are all narrow, only a single row of marginal cells being rather wider and pellucid.

Since the publication of this species by Thériot & P. de la Varde, I have received two plants, coll. H. A. W., which must certainly also be referred there, viz. Goodoo Pass, Drakensberg, Natal, 1918 (No. 714), and Ladysmith, 1918 (No. 681), both c. fr. The original gathering was from Van Reenen, Natal.

Grimmia apocarpa (L.) Hedw. Hogsback, Tjumie, C.P., 1917; coll. D. Hend. (No. 356), c. fr.; and near Hogsback, Tjumie, 4-6000 ft., 1916; coll. Hend. (No. 210), c. fr. An elongate form with rigid stems and leaves and very short hair-points. The leaf apex is very commonly orange-brown. This decoloration occurs on leaves at all parts of the stem and does not appear to be due to temporary conditions. The leaves are widely spreading when moist and the habit is somewhat that of *G. rivularis*; but there appears to be no central strand, and a short and inconspicuous hair-point is often present.

G. commutata Huebn. Dohne Hill, C.P., 5000 ft., 1898; coll. Sim (No. 7218), c. fr. Prof. Wager gives it also from "Rydal Mt." in his 'Check-list of the Mosses of S. Africa.'

G. pulvinata var. *obtus*a Brid. Probably frequent. *G. Eckloni* Sprengel is certainly the same thing.

Rhacomitrium austro-patens (C. M.) Broth. Gaika's Kop, 6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 240), c. fr. One or two old and imperfect capsules are present and a single immature one; these show a very short, straight seta, only a few millimetres long, and a small, elliptic capsule.

R. symphyodontum (C. M.) Par.* Giant's Castle, 8000 ft., Natal, 1915; coll. R. E. Symons, comm. Sim (No. 8697). I cannot separate this in any way from the widely distributed Australasian and subantarctic species except that the nerve is very slightly narrower than is usual, but this can be quite matched by specimens I have of that plant. The distribution of the species is quite in favour of the identification, as it is recorded from Patagonia, Fuegia, Falklands, New Zealand and Tasmania, and I have it also from Victoria, Australia, and also from the New Hebrides.

ORTHOTRICHACEAE.

Diplostichum Mont. (*Syn. Eustichia* [Brid.] Mitt.).

On the nomenclature of this genus see the important note by Cardot, 'Mousses de Madagascar,' p. 226.

? *Diplostichum longirostre* (Brid.) Card. Bushman's River, Natal.

* *Rhacomitrium crispulum* Hf. & W. appears to be the more correct name for this.

Nov., 1916; coll. Sim (No. 8535). There is some doubt as to the identity of the African plant with the original *Eustichia longirostris* (Brid.) from Tristan da Cunha; if distinct, then it would need to be ascertained whether our plant be identical or not with the Madagascar form. In the former case it would be *D. distichum* (Schwaeg.) Card.; in the latter it would require a new name. The differences suggested appear at best to be slight.

D. africanum C. M. Sweetwaters, Natal, Feb., 1917; coll. Prof. Bews, comm. Sim (No. 8636). Quite distinct from the other African species in the small size, very small, julaceous leaves, straight apiculus, and smaller cells.

Anoetangium Wilmsianum (C. M.) Par. Goodoo, 6500 ft., Drakensberg, 1915; coll. Prof. Bews, comm. Sim (No. 8380). Top of Drakensberg, 8000 ft., Basutoland, 1915; coll. R. E. Symons, comm. Sim (No. 8662), c. fr.; Giant's Castle, 8000 ft., Natal, 1915; coll. R. E. Symons, comm. Sim (No. 8659). I name these plants with little hesitation from C. Mueller's description of *Zygodon Wilmsianus*.

Zygodon Simii Dixon, sp. nov. (Pl. XI, fig. 8.)

Z. runcinato C. M., affinis, habitu simimillimus. Differt foliis latioribus, e basi late ovali late lanceolatis, breviter late acuminatis, valde recurvo-squarrosis, conduplicatis; marginibus inferioribus late valde recurvis, ad partem tertiam superiorem multo minus fortiter dentatis, dentibus parvis inter majora spinulosa interjectis, costa tenuiore, dorso multo minus prominente. Sterilis tantum notus.

Hab.—Top of Zwaartkop, 5000 ft., Natal, 1917; coll. Sim (No. 8690). Forming extensive cushions on nearly bare rock, mixed with *Selaginella rupestris*.

A fine species, with habit of *Z. runcinatus*, but quite distinct in the wider leaves, much less coarsely toothed, the strongly recurved margins at base, less prominent, weaker nerve, etc. (*cf.* Pl. XI, fig. 11).

Orthotrichum glaucum C. M. Cape Town, on trees; coll. H. A. W. (Nos. 16, 568), c. fr. Hout Bay, C.P., 1916; coll. H. A. W. (No. 603), c. fr.

Macromitrium, subgen. Macrocoma. I have received several specimens belonging to *M. tenue* (Hook. & Grev.), *M. Dregei* Hornsch., etc., but I have not attempted at present to unravel the intricacies of the South African species of this subgenus.

Schlotheimia Grevilleana Mitt. Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (No. 321), c. fr., and Natal (No. 128), c. fr. Hogsback, Tjumie, C.P., 1917; coll. D. Hend. (No. 343), c. fr.

S. ferruginea (Hook. & Grev.) Brid. Giant's Castle, 6000 ft., Natal, Nov., 1915; coll. R. E. Symons, comm. Sim. (No. 8534), c. fr. A curious form in dense cushions without any creeping stems; these, I think, have decayed away with age and dense growth of branching.

Schlotheimia, sp. A rather striking species was gathered on Hogsback, Tjumie, 4-6000 ft., 1916, by D., B. & M. Henderson (No. 224), and again in 1917 by D. Henderson (No. 348). It is rather slender in habit, with long, substoloniferous stems bearing longly and finely pointed leaves, and marked in its colouring, being deep bright green above and bright rusty red below. In absence of fruit, however, it does not seem possible to determine.

FUNARIACEAE.

Physcomitrium spathulatum C. M. Maritzburg, 1916; coll. Sim (No. 8539), c. fr.

Funaria Bergiana (Hornsch.) Broth. Knysna, C.P., 1916; coll. H. A. W. (No. 531), c. fr.

F. marginata (C. M.) Broth. Kaapsche Hoop, 6000 ft., Transvaal, 1915; coll. H. A. W. (No. 296), c. fr.

F. Rottleri (Schwaeg.) Broth. Knysna, C.P., 1916; coll. H. A. W. (No. 560), c. fr.; Camps Bay, C.P., 1916; coll. H. A. W. (No. 600), c. fr. The leaves vary on the same stem from entire or subentire to sharply denticulate, and the nerve is at times, I believe, excurrent. *F. campylopodoides* (C. M.) is, I suspect, the same thing.

BRYACEAE.

Mielichhoferia Rehmannii C. M. Van Reenen Pass (No. 65) and Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (Nos. 314, 322, 336), all c. fr. C. Mueller (Hedwig., xxxviii, p. 64), in describing this species, states that the peristome is internal only, adding a note—"peristomium externum rudimentarium prius errore vidisse credidi." Wager's 314 confirms C. Mueller's first observation in a very interesting way. The first peristome I examined showed well-developed outer teeth, about .6 mm. long, yellowish below, pale above, internally trabeculate. Capsules later examined showed no outer teeth, nor did I find any on No. 322. The internal peristome also varied a good deal, the processes being rarely fully developed. The leaves are not always "integerrima," as C. Mueller describes them, but often denticulate.

Orthodontium lineare Schwaeg. George, C.P., 1916; coll. H. A. W. (No. 542), c. fr. By the kindness of the keeper of the Herb. Boissier I have been able to examine part of Schwaegrichen's type; this agrees with the present plant exactly as far as it goes, and I have no hesitation in referring it there. Unfortunately the capsules of the type showed no complete peristome. Wager's plant has the peristome in good condition, showing short, almost smooth, cuneiform outer teeth, rather distantly articulate, with very narrow-linear, smooth, articulate inner processes, markedly longer than the teeth. C. Mueller's description of the teeth as densely barred and the

processes as equal to the teeth in length does not agree, but as he had not seen actual specimens too much stress must not be laid on this discrepancy.

The plication of the capsule is very variable, often wanting.

Leptobryum piriforme (L.) Wils. George, C.P., 1916; coll. H. A. W. (No. 570), c. fr.; Maritzburg; coll. Sim (No. 8676). There may be some question whether this is not an introduced plant.

Pohlia mielichhoferiacea (C. M.) Broth. Van Reenen Pass, Natal, 1915, coll. H. A. W. (No. 285), c. fr. I think this plant is referable to *C. Mueller's* species, though there are certain discrepancies. Rehm. M. Austr.-Afr. No. 222 agrees very well except that the plants are very scattered; here they are somewhat coespitose. The leaves of the fertile stems are there much longer and narrower, those of the sterile stems shorter and less acute, with shorter and more obscure cells. The inflorescence, capsule and peristome, however, agree quite well, and in view of the peculiar nature of the peristome this must have considerable importance.

P. nutans (Schreb.) Lindb. (Syn. *Bryum Ecklonianum* C. M.). George, C.P., 1916; coll. H. A. W. (No. 552), c. fr. *Bryum Ecklonianum* C. M. is certainly the same thing.

Brachymenium dicranoides (Hornsch.) Jaeg. Home Rule, 5000 ft. Poleta, Natal, June, 1915; coll. Sim (No. 8666), c. fr.

Brach. Borgenianum Hampe. Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (No. 331), c. fr.

Brach. campylotrichum (C. M.). (*Bryum campylotrichum* C. M. in Hedwig. xxxviii, 65.) Rietfontein, Transvaal, coll. H. A. W. (No. 253 p.p.). This appears to be *C. Mueller's* species, with the description of which it agrees well. It is closely allied to *B. pulchrum*, but differs at once in the scarcely bordered leaves.

Brach. pulchrum Hook. Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (No. 339), c. fr. Near Hogsback, 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (Nos. 195, 211), c. fr. Trees near top of Zwaartkop, 5000 ft., Natal, 1917; coll. Sim (No. 8701), c. fr. Giant's Castle, 8000 ft., Natal, 1915; coll. R. E. Symons, comm. Sim (No. 8692).

I have compared specimens of *Brach. koratranum* (C. M.)—"Cap B. Sp., Phillipstown, am Kat-River, misit Ecklon," in Herb. Hampe, probably part of the original co-type of *B. koratranum*—and the original of *B. pulchrum* in Herb. Hooker, and I do not find the differences alleged by *C. Mueller* to hold good between the two. The principal characters, as noted by *C. Mueller* (Syn. i, 324), are as follows:

B. pulchrum he compares with *B. koratranum* as "quam maxime simile, sed foliis angustioribus, sublancoelatis longioribus margine minus pellucidis et theca brevi-pedunculata brevicolla sat differt." The fruit of the former he describes as "pyriformis rotundata," that of the latter as "pyriformis clavata."

Hooker's specimens of *B. pulchrum* do not at all bear out this description of the form of the leaves; they are no narrower and no less concave. They may be subentire or subdenticulate on the same stem. The nerve shows no difference such as the description implies; in both plants in the upper leaves it usually runs out clearly into the arista; there is no difference in the border. Nor are the fruiting characters in any way distinguishable. The seta varies in length in the same tuft considerably, as do the capsules in form; they are, in fact, clavate before maturity, but when fully ripe more inflated. The two plants are indubitably identical.

Anomobryum promontorii (C. M.) Dixon comb. nov. (syn. *A. procerrimum* Rehm. *Bryum promontorii* C. M.). Near Hogsback, 4-6090 ft., Tjumie, C.P., 1916; coll. Hend. (No. 222). Giant's Castle, 7000 ft., Natal, 1915; coll. R. E. Symons, comm. Sim (No. 8696).

In 'Bull. Torr. Bot. Club,' xliii, p. 68, I remarked on the confusion in the synonymy of this species, but I have to confess having needlessly added to its complexity. I gave there as the correct name *Anomobryum procerrimum* Rehm. Musci Austr.-Afr., 540. But as Mr. Sim has pointed out to me this is a *nomen nudum*, not being accompanied by a description. The first name published with a description was *Bryum promontorii* C. M. in Hedwig. xxxviii, 69 (1899), and I have therefore restored this specific name as above.

Bryum aulacomnioides C. M. Hogsback, Tjumie, C.P., 1917; coll. D. Hend. (No. 336). This agrees well with an authentic specimen at Kew, Rabenh. Bryoth. Eur. 1393, coll. MacOwan. I am inclined to think it is probably identical with *B. austro-ventricosum* Ren., from Madagascar, which I have not seen.

Bryum argenteum L. var. *australe* Rehm. Among various forms of *B. argenteum* received from South Africa the following are, I think, referable to this variety, which, while occasionally rather indistinctly marked, is, in its best developed condition, a very fine form. I have recorded it from several localities in South India. There it fruits readily, but I have not seen the fruit from Africa. Giant's Castle, 8000 ft., Natal, 1915; coll. R. E. Symons, comm. Sim (No. 8693). Near Hogsback, Tjumie, C.P., 1916; coll. Hend. (No. 189); Bulawayo, Jan. 1900; coll. E. Sadler, comm. G. Webster (No. 933).

Bryum Muehlenbeckii Bry. Eur. Giant's Castle, 8000 ft., Natal; coll. R. E. Symons, comm. Sim (No. 8656); Tugela Gorge, 6000 ft., Natal, 1915; coll. Prof. Bews, comm. Sim (No. 8657); Upper Bushman's River, 7000 ft., Drakensberg, Natal, 1905; coll. Sim (No. 8655).

These were sent as *Bryum afro-alpinum* (Rehm.); but they are not that, according to the specimen at Kew at least, which is *B. alpinum* Huds. simply. I cannot separate them in any way from our northern *B. Muehlenbeckii*, and think they must go there. No. 8655 is a lax form with weaker nerve, but cannot be separated from the others.

B. alpinum Huds. var. *viride* Husn. Majuba Nek, 6000 ft., Herschel, C.P., 1917; coll. Ivan Hepburn, comm. Sim (No. 8707). Hogsback, 4-6000 ft., Tjumie, C.P., 1917; coll. D. Hend. (No. 347). Two very diverse forms, the former a slender, small form, the latter robust and large leaved, coming near to var. *distentifolium* Dixon. Both, however, if collected in Europe I should certainly place in this variety.

B. canariense Brid. Kaapse Hoop, Transvaal, 1915; coll. H. A. W. (No. 313), c. fr. A fine, robust form. Cape Town, coll. H. A. W. (No. 339), c. fr.

B. canariensisforme Dixon. King William's Town, 2000 ft., C.P., 1893; coll. Sim (No. 7314), c. fr.

*B. Mundii** C. M. George, C.P., 1916; coll. H. A. W. (Nos. 536, 546, 558); Port Elizabeth, C.P.; coll. H. A. W. (No. 100); Knysna, C.P.; coll. H. A. W. (No. 525); Dohne Hill, C.P., 4508 ft., 1898; coll. Sim (No. 7206). Mostly c. fr.

Bryum truncorum Bory. Pirie Forest, 4000 ft., C.P., 1893; coll. Sim (No. 7278), c. fr.; Grahamstown, C.P., comm. G. Webster (No. 386); Waterval, Transvaal, 1914; coll. H. A. W. (No. 299), c. fr.; Hogsback, Tjumie, 1917; coll. D. Hend. (No. 342).

There is a good deal of confusion in the S. African plants of the Rosulata Group of *Bryum*. Certain forms were for long referred to *B. canariense*, or equally to *B. Billardieri* Schwaegr., or considered as varieties of these. C. Mueller separated these, or some of them, as *B. Mundii*, but this species has been misunderstood by later bryologists; while the difficulty is accentuated by the fact that *B. canariense* does actually occur in South Africa as well as *B. Mundii*.

Hampe's specimens in the British Museum collection, for instance, named *B. Mundii*, are most or all of them a quite different species, having a broad whitish or pale border of numerous rows of narrow, incrassate, sub-cartilaginous cells, the leaves more twisted when dry, the margin more strongly recurved, etc. *B. Mundii* is quite clearly described by C. Mueller as scarcely bordered, margin very narrowly recurved, and only near base, etc., and its close relation to *B. canariense* would quite preclude Hampe's plants being referred to it. The question is, what are Hampe's plants? They are mostly from the Cape, without collectors' names, but are clearly from some of the earlier collectors, e.g. Ecklon, Breutel, Zeyher; and the same plant has been sent to me by various collectors in different parts of S. Africa. After careful comparison I make no doubt that they belong to *B. truncorum* Bory, recorded hitherto only from the East African Islands, principally Reunion. I have not been able to examine original specimens, but I have studied Bescherelle's specimens from I. Bourbon, coll. Duisabo, de l'Isle, etc.

* C. Mueller writes it *Mundtii*, but there is no doubt of the collector's name being Mund.

Bescherelle may be assumed to have known the species of Bory. Vegetatively the S. African plants agree exactly with, *e. g.*, de l'Isle's specimens. The fruiting characters, as far as I have examined them, also agree, though the seta and capsule in Duisabo's specimen—the only one in good fruiting condition—are slightly longer than in the general run of the S. African plants.

There is no reason, of course, why the species should not be common to Reunion and the African continent; indeed, the more doubtful question is whether there is any true specific distinction between this and some of the other southern plants of this group, *e. g.* the Australasian *B. leptothecium* Tayl., and the S. American *B. Lechleri* Schimp—whether in fact it is not one widely distributed species ranging over the whole subantarctic region. As to this, however, I do not venture an opinion.

It may be helpful to give in the form of a key some of the salient distinguishing characters of the four S. African species of this group. *B. polytrichoides* C.M. is a much smaller plant with quite different leaf, and appears to me to belong not here but to group *Trichophora*.

- | | | |
|----|---|-------------------------|
| | Comal leaves suberect when moist, small, 2-3 mm. long, not or scarcely bordered | 2 |
| 1. | Comal leaves widely spreading, large, 4 mm. long or more, with a more or less distinct border of at least 1-2 rows of very narrow, incrassate cells | 3 |
| 2. | Margin recurved (often strongly) | <i>canariense</i> |
| | Margin plane | <i>canariensisforme</i> |
| | Border narrow, of about 2 rows of usually brownish cells; leaves erect and little twisted when dry | <i>Mundii</i> |
| 3. | Border (especially below) very broad, of numerous rows of pale, whitish cells; leaves more or less twisted when dry | <i>truncorum</i> |

Bryum (§ *ROSULATA*) *pumili-roseum* Dixon, sp. nov. (Pl. XI, fig. 9.)

Humile, densiuscule coespitosum; saturate viride; caules *viz* 1 cm. alti, inferne ad secundam tertiam partem nudi seu foliis minutissimis squamatis vestiti, superne abrupte comati, foliis siccis flexuoso-contortis, madefactis faciliter emollientibus, horizontaliter patentibus, *rosulam pulchram confertam minutam, circa 5 mm. latam* instruentibus. Folia comalia 2-3 mm. longa haud decurrentia, e basi brevi paullo angustiore late obovata vel spathulata, subacuta; costa infra valida, supra angusta, in *cuspidem seu mucronem sat validum perbreveem reflexum* subintegrum vel denticulatum excurrentis; sectione subteres, e cellulis *homogeneis fere*, externis 1-stratosis tantum paullo majoribus instructa, *ducibus nullis*. Margines saepius uno latere tantum basin versus recurvi, reliquo plani, superne dentati. Cellulae superiores *parvae*, 10-16 latae, rhomboideae, regulariter ordinatae, parietibus firmis, haud incrassatis, marginalibus 2-4 seriebus angustissimis, anguste linearibus, incrassatis, limbum *validum, rufescentem* formantibus.

Inter folia comalia saepe *propagula numerosa* longa, crassa, rhabdiformia *articulata* inveniuntur. Cetera ignota.

Hab.—Hogsback, 4000 ft. alt., Tjumie, C.P., 1917; coll. D. Henderson (Nos. 326, 327, 337).

A pretty little species forming neat, dense, minute rosettes after the manner of *Rhodobryum roseum*, but far smaller. It is quite distinct from any of the species of the group known to me, and for that reason I have not thought it needful to include it in the above key.

Rhodobryum umbraculum (Burch). Par. Near Lovedale, C.P., 1913; coll. Rev. Jas. Henderson (No. 92); Hogsback, Tjumie, C.P., 1917; coll. D. Hend. (No. 329); Pirie Forest, 4000 ft., C.P., 1892; coll. Sim (No. 7226, c. fr.); Maritzburg, 1909; coll. H. A. W. (No. 4), c. fr.

Rhodobryum roseum (Weis) Limpr. (syn. *Bryum leucothrix* C. M.). Near Hogsback, alt. 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 201c); Dohne Hill, 5000 ft., C.P., 1898; coll. Sim (No. 7215); Poleta, 4000 ft., Natal, 1914; coll. I. W. Haygarth, comm. Sim (No. 1), c. fr.

I had determined the S. African plant as *R. leucothrix* (C. M.) Broth. so long as I had seen only the sterile plants, since it was possible that the fruit might reveal some differences from *R. roseum*; the Poleta gathering, however, shows that the fruit is exactly identical with that widely-spread species. Mitten refers Central African plants to the same species, and some Tropical African plants which I have seen certainly belong here, though it must not be assumed, I think, that all the allied plants in that region belong to a single species.

MNIACEAE.

Mnium rostratum Schrad., var. nov. *Reidii* Dixon.

Caules steriles *longissimi*, usque ad 2 pedes et ultra, pendentes, hic illic ramosi, pulchre frondiformes.

Hab.—Town Bush, Maritzburg, on face of wet rock with *Cystopteris fragilis* and *Streptocarpus*, coll. A. Reid; and also later by Sim (No. 7552).

In spite of the remarkable development of this plant, which was sent me by Mr. Sim under the name of *M. Reidii* sp. nov., it must, I think, be considered a variety of *M. rostratum*—a species which is not infrequent in S. Africa.

RHIZOGONIACEAE.

Rhizogonium vallis-gratie (Hampe) Par. Blinkwater Ravine, 3000 ft., 1917, coll. Prof. Bews, comm. Sim (No. 8586). A strikingly different plant from most of its congeners.

BARTRAMIACEAE.

Bartramia. Several of the S. African species of this genus, notably the gymnostomous species of § *Strictidium* and some of the § *Vaginella*, present considerable difficulties and consequently involved synonymy, which at present I have not been able to clear up to my satisfaction. I am inclined to think that one or two of the species are exceedingly variable, and that this has led to an undue multiplication of names. I hope before long to be able to elucidate some at least of these obscurities. One reduction I can make with certainty. *B. afro-stricta* C. M. is entirely identical with *B. substricta* Schimp., as a comparison of Rehm. M. Austr.-Afr. 203, 204, 205, with Schimper's type at Kew shows.

I have received this species from Table Mt. and from Camps Bay, C.P., coll. H. A. W. (No. 597).

Philonotis androgyna (Hampe) Jaeg. Knysna; and George, C.P., 1916; coll. H. A. W. (Nos. 526, 537), c. fr. Slightly more compact and shorter than Hampe's original plant, but inflorescence and general structure the same.

P. laxissima (C. M.) Bry. Jav. Albert Falls, Natal, 2000 ft., 1917; coll. Sim (No. 8704). Near Hogsback, 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 186). The latter plant at least is *P. curvifolia* Besch.; but that and probably *P. tenuicula* (Hampe) Besch. are scarcely more than forms of *P. laxissima* (C. M.) Bry. Jav.; cf. Cardot, 'Mousses de Madagascar,' pp. 308 sqq.*

P. delagoae (C. M.) Broth. George, C.P., 1916; coll. H. A. W. (No. 5000), c. fr. I have determined this from the description (of the sterile plant). C. Mueller described his species as with the margin "ubique erecto," but Brotherus places it in a section having recurved margin; Prof. Wager's plant has it recurved. The peristome is double, inner reddish below, processes imperfect, shorter than the outer teeth, smooth or nearly so.

P. mauritiana Aongstr. Hogsback, 4-6000 ft., Tjumie, C.P., Jan., 1916; coll. Hend. (No. 193), and again, 1917, coll. D. Hend. (No. 353). Cardot refers *P. luteo-viridis* Besch. to this species.

P. hymenodon (C. M.) Jaeg. Gaika's Kop, 6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 228). Agrees quite well in structure with Rehm. M. Austr.-Afr. 186, but is much taller and more robust, 5-6 cm. high and of *Philonotoid* habit.

P. afro-fontana (C. M.) Par. (Syn. *P. oraniae* Rehm.). Wet bank of stream, Pretoria, 1910; coll. H. A. W. (No. 2); Estcourt, 4600 ft., 1913;

* I have this species from Joseph's Well, Maturieh, near Cairo, 1911, coll. Miss Armitage (det. Dismier), and also from El Marg, Cairo, on damp ground near water, April, 1910; coll. D. C. Eady.

coll. R. C. Wroughton, comm. W. R. Sherrin (No. 2) ; Hogsback, 4-6000 ft., Tjumie, C.P., 1916 ; coll. Hend. (No. 223) ; and again, 1917 ; coll. D. Hend. (Nos. 322, 339). All sterile.

Paris has made a good deal of confusion in the synonymy of this species and *P. afro-uncinata*. The vars. *breviset*a and *gracilescens* belong to the latter species, and "*Bartramia afro-fontana* var. . . ." should read "*B. afro-uncinata* var. . . ." in each case.

In an original specimen at Kew on some stems the leaves are distinctly serrate, in others not at all.

Breutelia afro-scoparia (C. M.) Par. Gaika's Kop, 6000 ft., Tjumie, C.P., 1916 ; coll. Hend. (No. 227) ; Giant's Castle, 7000 ft., Natal, 1915 ; coll. R. E. Symons, comm. Sim (No. 8668). A fine species, very like the European *B. arcuata*, but differing in essential points. C. Mueller describes it "e cellulis perminutis pallidis maxime lineari-angustis ubique areolata," but this is quite misleading. I have examined an original specimen of MacOwan's, and find that there, as well as in the specimens cited above, there are numerous rows of subquadrate alar cells reaching some distance inwards.

B. aristaria (C. M.) var. *plumosa* C. M. Near Hogsback, Tjumie, 4-6000 ft., C.P., 1916 ; coll. Hend. (No. 209).

From the description of *B. Spielhausii* C. M. I should greatly doubt if it be distinct from this robust, long-leaved var. of *B. aristaria*.

? *B. subgnaphalea* (C. M.) Par. Town Bush, 3000 ft., Maritzburg, 1916 ; coll. Sim (No. 8702). A sterile plant, which in absence of fruit cannot be determined with certainty, but in all probability belongs here, as it agrees vegetatively. *B. subgnaphalea* shows some variation in the alar cells, of which there are frequently two or three rows laxer and shorter than the median, but frequently these are wanting and there is only a single marginal row of narrow cells, almost similar to the rest except for being quite pellucid.

PSILOPILUM Brid.

This distinct genus of Polytrichaceae has not yet been recorded from Africa. The species are few and their range restricted ; it is therefore remarkable that two species, both new and quite distinct from one another, should have been almost simultaneously collected. The genus is marked by the glabrous calyptra (only one species shows a few erect hairs), the laterally compressed, usually curved, asymmetrical capsule, the rather undeveloped peristome, which is sometimes wanting, and the sinuous lamellae of the leaves. These resemble the leaves of *Oligotrichum*, but have (with one known exception) no traces of lamellae on the back of the nerve.

The species hitherto described number about fifteen, four from the

boreal region of the old world, four from the higher mountains of tropical S. America, and the remainder from the antarctic and subantarctic region.

Psilopilum afro-laevigatum Dixon sp. nov. (Pl. XI, fig. 10.)

P. laevigato (Wahl.) Lindb. (*P. glabratum* Wahl.) affine; minus, *pusillum*, circa 5 mm. altum; foliis *mollibus*, spathulatis, apice late rotundatis, patentibus, minus *concavis*, apice *vix vel haud cucullatis*, marginibus *plus minusve regulariter obtuse dentatis*. Cellulae superiores hexagono-rotundatae, 16–20 μ , parietibus *pertenuibus*, pellucidae, dorso lenissime protuberantes. Lamellae perpaucae (circa 6), marginibus *irregulariter crenatis*.

Hab.—Rosetta, Natal, alt. 4000 ft., Jan. 1915; coll. Sim (No. 8068).

Terminal flowers prove that the plant is full-grown, but the organs are too immature for it to be easy to decide if they are the ♂ or the ♀ plant. In either case they present a distinct difference from the European *P. laevigatum*. There the ♂ inflorescence has the very short, broad, apiculate, imbricated scale-like bracts usual in *Polytrichum*, while the ♀ inflorescence is not rosette-shaped, nor indeed at all enlarged, with only one or two floral leaves. Here the flower is rosette-shaped and forms a distinct, enlarged comal tuft, but the leaves are of normal, stem-leaf form, only longer, not imbricated and scale-like, as in the usual inflorescence of the genus.

For the nomenclature of the northern species of the genus cf. Hagen, 'Forarbejder til en Norsk Løvmosflora, Polytrichaceae,' and 'Bryologist,' xix, p. 70.

Psilopilum Wageri Broth. MS., sp. nov. (Pl. XII, fig. 12.)

Perpusillus; caulis vix 5 mm. altus; folia inferiora breviora, late ovato-lanceolata, patula; superiora angustiora, longiora, erecto-patentia, perichae-talia erecta; omnia late acuminata, subobtusata, apice cucullata, valde concava, marginibus involutis, integerrimis vel lenissime sinuatis; lamellae paucae (circa 5), marginibus integris vel hic illic leniter crenatis. Cellulae superiores subrotundatae, 13–16 latae, valde incrassatae. Costa subper-currens, dorso glabra. Seta 5–7 mm. alta, rubra; theca parva, 2–2.5 mm. longa, ovalis, curvata, asymmetrica, aetate compressa; peristomium 60–70 μ altum, dentibus 32, remotiusculis, triangularibus, inaequalibus, acutis, aurantiacis. Opereculum, calyptra, ignota. Exothecii cellulae hexagonae, omnes fere isodiametricae, parietibus tenuibus, orificium versus sensim minores, incrassatae.

Hab.—Rydal Mount; coll. H. A. W. (No. 45), c. fr.

This species will readily be separated from the last by the characters italicised. It is perhaps most nearly allied to the northern *P. cavifolium* (Wils.) (*P. tschutschicum* [C. M.], Par.), of which it has the small size, the entire leaves and entire or only faintly and obtusely sinuate-crenate margin of lamellae; but it differs in certain marked structural characters, especially of the sporophyte.

Pogonatum capense (Hampe) Jaeg. Giant's Castle, 7000 ft., Natal, 1915; coll. R. E. Symons, comm. Sim (No. 8245), c. fr.; Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (No. 312), c. fr.

Polytrichum trichodes C. M. Near Hogsback, 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 233).

Polytrichum commune L. I have received this from several stations in Cape Prov. and Natal. Specimens from George, 1916, coll. H. A. W. (No. 539), and Dohne Hill, C.P., 1898, coll. Sim (No. 7200), both c. fr., I should refer to var. *minus* Weis. A remarkably branched, fastigiate form from Gilletts, on clay bank on roadside, Natal, Oct., 1916, coll. Sim (No. 8542), is the var. *fastigiatum* Wils.; Mr. Sim writes that it is probably this which Dr. Shaw took to be *Polytrichum dendroides* Hedw., and which he states is in the herbarium at Kew from S. Africa.

ERPODIACEÆ.

Erpodium transvaaliense Broth. & Wag. sp. nov. (Pl. XII, fig. 13.) Ab *E. Holstii* Broth., cui proxima, differt tantum foliis magis hyalino-apiculatis, perichaetialibus præcipue apicem versus distincte incanis, in pilum plus minusve elongatum basi explanatum hyalinum integrum angustatis; atque cellulis folii magis isodiametricis, raro transverse elongatis.

Hab.—Wolhuter; coll. H. A. W. (No. 189).

I have not been able to see an authentic specimen of *E. Holstii* Broth., but a plant from Mt. Meru, German East Africa, which I take to be that species, differs only very slightly from the Wolhuter plant in the leaves scarcely hyaline-pointed, the perichaetial leaves having a short half-twisted apiculus usually brownish rather than hyaline. The cells in that are very regularly seriate, for the most part transversely elongate, while in *E. transvaaliense* they are usually isodiametric. The walls in both are thin, very slightly collenchymatous at the angles, but in the upper part of the leaves when hyaline, or under pressure or slight injury, they very readily—as is natural with large cells of delicate structure—collapse, and then have the false appearance of being widened and incrassate.

E. Pobeguini Par. & Broth. has rather smaller cells, with the walls more thickened.

E. distichum Wag. & Dix. sp. nov. (Pl. XII, fig. 14.) *E. grossireti* C. M. proxima; differt foliis omnibus obtusis, nullo modo apiculatis, perichaetialibus chlorophyllosis, areolatione ei foliorum verorum simillima; caules ramique prostrati, foliis subdistiche patentibus, siccitate erectis, conniventibus. Theca emergens.

Hab.—Barborton, Transvaal, 1914-15; coll. H. A. W. (No. 279); Maritzburg, 1915; coll. H. A. W. (No. 226).

E. grossirete C. M. is described as having the leaves at times apiculate,

imbricated, the perichaetial ones not chlorophyllous, with elongated, prosenchymatous cells. In these respects, therefore, it must differ markedly from the present species, which has the leaves and perichaetial bracts all obtuse, the former usually widely rounded at apex, while the areolation of the perichaetial bracts does not differ materially from that of the other leaves.

HEDWIGIACEAE.

Hedwigidium erosum (C. M.) Par. Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (No. 304). This may, I think, be considered distinct from *H. imberbe*; the leaf apex is often markedly erose-denticulate, though sometimes entire; occasionally there is a short hair-point. The perichaetial leaves are erose above and subundulate at margin, distantly ciliolate-toothed half-way down. Is *H. Macowanianum* (C. M.) in any way different?

Braunia Elliotii Broth. Hogshack, Tjumie, C.P., 1917; coll. D. Hend. (No. 334).

This plant agrees vegetatively exactly with the Central African species, and must certainly be referred there pending the discovery of fruit.

FONTINALACEAE.

Wardia hygrometrica Harv. Submerged in stream, Montagu Pass, C.P., 1916; coll. H. A. W. (No. 580).

NECKERACEAE.

Pilotrichella panduraefolia (C. M.) Jaeg. (syn. *P. Kuntzei* C. M.), Zwaartkop, 4500 ft., Natal, 1916; coll. Sim (No. 8571). A form with densely fasciated branches and branchlets, which Mr. Sim says he has several times found. Uitenhage, C.P., 1910; coll. W. Milne, comm. Ingham (No. 5). Natal; from skin of otter in British Museum; comm. W. R. Sherrin. Grahamstown, C.P., coll. J. Burton, comm. G. Webster (No. 348). Evelyn Valley, Pirie Forest, 4500 ft., C.P., 1892; coll. Sim (No. 7018), c. fr. This last is the plant described by C. Mueller as *P. Kuntzei*; Mr. Sim writes that he was with O. Kuntze in the Pirie Forest when he collected it, and remembers the moss attracting Kuntze's attention. C. Mueller describes it as being pale in colour, and that, indeed, is the only difference to be detected between it and *P. panduraefolia*.

Squamidium Rehmannii (C. M.) Broth. Katberg Mts., 1896; coll. Mrs. Clarke Williams, comm. C. H. Binstead (No. 17) det. Mitten; Tjumie, on Hogshack, C.P., 1917; coll. D. Hend. (No. 346b).

Neckera Valentiniana Besch. Grahamstown, C.P., 1910; coll. Miss Farquhar, comm. T. H. Russell (No. 14); Kaapsche Hoop, Transvaal, 1915;

coll. H. A. W. (No. 338); Knysna, C.P., 1916; coll. H. A. W. (No. 518); Cape of Good Hope; coll. F. Webster, comm. G. Webster (No. 343). Mostly c. fr.

I have spent a considerable time in endeavouring to distinguish between *N. Valentiniana* Besch. and *N. capensis* Schimp., and have been driven to the conclusion that they are inseparable. Brotherus distinguishes them as follows:

N. Valentiniana. Peristome teeth smooth, usually more or less distinctly transversely and obliquely striolate at base. Segments of inner peristome about equal in length to the teeth.

N. capensis. Peristome teeth finely papillose, at base transversely and obliquely striolate. Segments of inner peristome as in the last.

The supposed difference is therefore practically confined to the upper part of the outer teeth, being smooth in *N. Valentiniana*, finely papillose in *N. capensis*.

I find, however, too little constancy in this character to base a specific difference upon it. Thus Sim 7498 has the peristome teeth very finely papillose, with a very slight tendency to transverse striolation on a few of the lowest segments, while the processes are irregular, narrow, varying from half to two-thirds the length of the outer teeth in the same capsule; on the other hand most of the above specimens have the teeth smooth above. Moreover, Schimper's specimens of *N. capensis* do not always, at any rate, show papillose teeth, for in several capsules of his specimens at Kew (coll. Zeyher) the teeth are quite smooth above and only here and there show a little basal striolation.

I find no constant difference in the leaf apex.

Bescherelle gives some differences between *N. Valentiniana* and *N. africana* Schimp., but these, too, are not borne out by Schimper's specimens under that name at Kew. As both *N. capensis* and *N. africana* are *nomina nuda*, Bescherelle's name must stand. I have compared S. African specimens with *N. Valentiniana* Besch. (coll. Valentin), and also with the Madagascar plant, "1875, misit Borgen, comm. Kiaer," in Herb. Besch., and they agree quite well. This is no doubt the *N. Borgeniana* Kiaer, and as Bescherelle identified it with his *N. Valentiniana*, I think the two may be accepted as identical. Cardot has expressed the same opinion, only a little less certainly, in the 'Mousses de Madagascar.' The degree of acuteness of the leaf apex is certainly quite inconstant and not correlated with any other characters. The perichaetial leaves in Schimper's specimens are sometimes longer, sometimes shorter than the deoperculate capsule on the same plant. I think that without doubt *N. Borgeniana* Kiaer, with the MS. names *N. capensis* Schimp., *N. africana* Schimp., and *N. undulatifolia* Mitt., must be sunk in the synonymy of *N. Valentiniana* Besch.

ENTODONTACEAE.

Entodon geminidens Besch. Barberton, Transvaal, 1916; coll. H. A. W. (No. 254). This species is characterised by, *inter alia*, the forward direction of the leaves—i. e. the acute angle they make with the stem and the comparatively few alar cells.

E. brevirameus Dixon. Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (Nos. 289, 323), c. fr.; Woodbush, Transvaal, 1915; coll. H. A. W. No. 137), c. fr. This species is very near to *E. lacunosus* Broth., but the peristome does not agree.

E. natalensis C. M. Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (Nos. 291, 307), c. fr. No. 291 differs from the type-form in the longer seta, in that it is given by Brotherus as about 8 mm. long, and Rehm., M. Austr.-Afr. 331, agrees with that statement. Rehm. 650, however, differs somewhat in having the setae 12-14 mm., often in pairs, the capsule more longly cylindric and deeper in colour. Wager's No. 291 agrees with this, and I thought it at first worthy of varietal rank. No. 306, however, shows so much variation in length of seta that I think it is scarcely desirable to give it that position.

Levierella fabroniacea C. M. var. *abyssinica* (Broth.) Dixon, comb. nov. (Syn. *Levierella abyssinica* Broth. in Engler & Prantl, 'Pflanzenfam., Musci,' ii, p. 894; *Rozea abyssinica* Broth., MS. in Herb. Berol., etc.; *Cylindrothecium abbreviatum* Schimp., MS. in Herb.; *Entodon cyrtocladus* Besch., MS. in Herb.; *Cylindrothecium cyrtocladon* Besch., in Herb. Mus. Paris.)

Hab.—Abyssinia; coll. Quartin Dillon & Petit, 1844; Abyssinia; Amba Sca, 6000 ft., Tigre, Sept. 5th, 1847, in W. P. Schimper, M. Abyssin., No. 427. Kaapsche Hoop, Transvaal, 6000 ft., 1915; coll. H. A. W. (Nos. 301, 305), c. fr.

The Kaapsche Hoop plant agrees quite well with Bescherelle's *Cyl. cyrtocladon*. On careful comparison with the Indian plant I can find no difference whatever beyond a slightly more acute toothing of the margin of the leaf. The African plant, which has not been described as a species, is, I think, at best a variety of *L. fabroniacea*. I have received it from several localities in Central Africa.

Entodon cymbifolius Wager & Dixon sp. nov. (Pl. XII, fig. 24.) Caules prostrati, dense intertexti, caespites humiles, late extensos laete virides, nitentes, intus pallidos, formantes; 5 cm. longi, sat robusti, *confertiuscule regulariter pinnati*, ramis circa 5 mm. longis, siccitate saepe curvatis, subteretibus nullo modo *complanatis*. Folia caulina conferta, erecto-patentia apicibus incurvis, *cymbiformi-concava*, circa 1 mm. longa, late ovata, acuta vel obtuse apiculata vel nonnumquam subobtusa, integra vel plerumque ad apicem irregulariter minute denticulata; breviter bicostata; cellulis peranguste vermiculari-linearibus, chlorophyllosis, apud apicem brevioribus,

lterioribus, alaribus *haud numerosis*, quadratis, plerumque valde chlorophyllosis, opacis. Folia ramea similia, minora, breviora.

Autoicus. Folia perichaetialia omnes *erecto-appressa*, e basi vaginante longa *sat breviter latiuscule stricte* acuminata, integra. Setae singulae, *breves*, 6-8 mm. altae, *tenues, flavae*; theca *parva*, anguste elliptica, (deoperculata) 2 mm. longa. Peristomium, operculum, *haud visa*.

Hab.—Moorddrift, Waterberg District, Northern Transvaal, 1916; coll. H. A. W. (No. 408).

A very distinct species in the small cymbiform leaves, short seta, etc. *E. stereophylloides* Broth. would seem to be the only species at all near it. This I have not seen, but from the description it differs considerably, *inter alia*, in the leaves only moderately concave, more pointed ("ovato-acuminata"), and the perichaetial leaves filiform pointed.

Stereophyllum odontocalyx (C. M.) Par. Barberton, Transvaal, 1914; coll. H. A. W. (No. 261), c. fr.; Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (Nos. 261, 328), c. fr. No. 261 was sent me for description, as *S. Wageri* Broth. sp. n. I cannot, however, separate it from *S. odontocalyx*. I presume the subentire perichaetial leaves form the ground for its separation, but in plants from Rhodesia, coll. F. Eyles, Herb. Mus. Brit., I find them sometimes very little toothed while at other times fairly normal, and I think it is impossible to found a new species on this character alone.

FABRONIACEAE.

I find the S. African species very difficult to elucidate, and I do not feel at present to have at all mastered them. This is partly due to the fact that the leaves show much variability even on the same plant, in the degree of dentation of the margin, and to some extent also in the strength of the nerve and the character of the areolation. The difficulty also in part arises from C. Mueller's having described several species of which specimens are not available in our national collections, and which it is not easy to recognise from the descriptions alone, added to which there is an extreme probability, almost amounting to certainty, that some at least of his species are identical with species already described from tropical or sub-tropical Africa.

A considerable portion of the S. African specimens I have seen appear to me identical with *F. abyssinica* C. M., which may be roughly described thus: Tufts grey with the leaf-points, owing to the great density of the leaves; leaves moderately denticulate, long pointed, areolation rather obscure, not very chlorophyllose nor pellucid; capsule rather wide and subglobose, with an indistinct collum.

Several other plants I cannot separate from *F. angolensis* Welw. & Duby. This is a rather dark green plant, with the leaves much less densely arranged, and hence the tufts are not grey, the leaves are greener and more chloro-

phyllose, with pellucid cells, the margins less toothed, often almost entire, but variable; the capsule, especially when dry and empty, tapers conspicuously into a rather marked distinct neck. The lid is convex with a somewhat high apiculus, but scarcely rostellate, and this appears to separate it from *F. transvaaliensis* C. M., which is described as having an obliquely rostellate lid. *F. Rehmannii* C. M. differs from both in having the leaves almost entire, and the capsule subglobose, almost without trace of lid.

The following records are given, however, with some degree of uncertainty:

Fabronia angolensis Welw. & Duby. Moorddrift, Waterberg District, Northern Transvaal; coll. H. A. W. (No. 401), c. fr.; Hout Bay, near Cape Town, 1916; coll. H. A. W. (No. 602), c. fr.

Fabronia Rehmannii C. M. George, C.P., 1916; coll. H. A. W. (No. 561), c. fr. This agrees quite well with Rehmann's plant.

F. abyssinica C. M. (syn. *F. Schweinfurthii* C. M., *F. vallis-gratiae* Hampe). Moorddrift, Waterberg District, Transvaal, 1915; coll. H. A. W. (Nos. 400, 405), c. fr.; Pretoria, 1915; coll. H. A. W. (No. 1a), c. fr.; earth between rock and tree, 4900 ft., Salisbury, Rhodesia, 1917; coll. Fred. Eyles (No. 684a), Herb. Mus. Brit., c. fr.

These plants agree well with Schimper's specimens of *F. abyssinica* at Kew. I have also carefully compared original specimens of the two species cited above as synonyms, and can find no difference of any value. C. Mueller lays stress on the winged column of the capsule in *F. Schweinfurthii*, but this is very inconstant, and appears to me a question of the capsule drying in a certain particular condition. The vegetative characters he gives I cannot verify on the original specimens. *F. vallis-gratiae* appears to me a slightly more slender form, with the capsules somewhat narrower because gathered at an earlier stage.

F. pilifera Hornsch. Nottingham Road, Natal, 4500 ft., 1917; coll. Dr. P. van der Bijl, comm. Sim (No. 8695), c. fr.

F. perciliata C. M. Pretoria, and Rietfontein, Transvaal; coll. H. A. W. (Nos. 284, 282); Giant's Castle, 7000 ft., 1915; coll. R. E. Symons, comm. Sim (No. 8694); trees, Bulawayo, 1900; coll. E. Sadler, comm. G. Webster (No. 417); rock, Woodbush, Transvaal, 1910; coll. T. Jenkins, comm. W. Ingham (No. 3). All c. fr.

I have some hesitation about these plants, not having been able to see authentic specimens of *F. perciliata* for comparison. They appear to agree with the description, but on the other hand they come very near to *F. abyssinica*, differing principally, if not entirely, in the denser foliation and more strongly toothed leaves. The degree of toothing varies very greatly on different stems of the same plant.

F. Wageri Dixon. I have received several fruiting specimens of this from Prof. Wager, all from Cape Town (Nos. 92, 362, 366).

Helicodontium lanceolatum (Hampe & C. M.) Jaeg. George, C.P., 1916; coll. H. A. W. (No. 541), c. fr. I have compared this with the type in Hampe's herbarium. The seta is only faintly scaberulous. The leaves are remarkably like those of *Amblystegium serpens* (L.), only with numerous subquadrate alar cells.

Dimerodontium africanum C. M. Near Cape Town, 1915; and George, C.P., 1916; coll. H. A. W. (Nos. 346, 561 p.p.), c. fr.; King William's Town, C.P., 1892; coll. Sim (No. 7116), c. fr.

HOOKERIACEAE.

Cyclodictyon vallis-gratiae (Hampe) Broth. Kaapsche Hoop, Transvaal, 1915; coll. H. A. W. (No. 334) c. fr.; Hogsback, Tjumie, C.P., 1917; coll. D. Hend. (No. 359), c. fr.

HYPOPTERYGIACEAE.

Hypopterygium pennaeforme (Thunb.) Brid. Knysna, C.P., 1916; coll. H. A. W. (No. 522). ♀ flowers are present, and the plant seems dioicous, as stated by Brotherus. Kindberg makes it monoicous. He also says the leaves are bordered with one row of cells; here the border cells are mostly 2-seriate.

LESKEACEAE.

Lindbergia viridis Dixon sp. nov. (Pl. XII, fig. 15.)

Inter *L. pseudoleskevoidem* Dixon et *L. haplocladioidem* Dixon ludens; ab illa habitu graciliore, colore viridiore, foliis acutioribus, costa tenuiore, cellulis pellucidis; ab hac colore, foliorum acumine multo brevior, cellulis isodiametricis, etc.; a *L. patentifolia* Dixon nova sp., ex Africa tropicali, foliis minus patentibus, habitu multo graciliore, minus stricto, foliis minoribus, angustioribus, costa paullo latiore, foliis perichaetialibus strictioribus, areolatione longiore, angustiore. E speciebus quattuor africanis gracillima. Seta brevis, 7-8 mm. alta, tenuis; theca parva, anguste cylindrica. Peristomii dentes pallidi, ligulato-lanceolati, superne parum angustati, dense grossiuscule papilloso, saepius, praecipue superne, papillis opaci. Endostomii membrana basilaris circa tertiam partem longitudinis dentium aequans, papillosa, subpellucida; processus nulli.

Hab.—Kaapsche Hoop, Transvaal, on wood, 1915; coll. H. A. W. (No. 310).

The most slender and delicate of the known African species, of which five have now been described. The following may serve as a key to these species:

- | | | | |
|----|---|--|----------------------------|
| 1. | { | Leaves lanceolate, gradually tapering to a long narrow acumen ; not appressed when dry ; upper cells elongate, elliptic | <i>L. haplocladioides</i> |
| | { | Leaves wider, with short points, appressed when dry | 2 |
| 2. | { | Leaf apex recurved when dry | <i>L. abbreviatum</i> |
| | { | Branches terete when dry | 3 |
| 3. | { | Cells opaque, nerve thick, opaque ; leaf apex short, wide | <i>L. pseudoleskeoides</i> |
| | { | Cells pellucid, nerve thin ; acumen narrow, acute | 4 |
| 4. | { | Leaves cordate, spreading almost at right angles when moist, with incurved points, branches straight | <i>L. patentifolia</i> |
| | { | Leaves narrower, erecto-patent when moist, acumen straight, branches slightly curved, very slender | <i>L. viridis</i> |

Lindbergia pseudoleskeoides Dixon. Moorddrift, Waterberg District, Transvaal, 1916 ; coll. H. A. W. (Nos. 407, 412, 413), c. fr. M. Thériot has, moreover, sent me a specimen of this species from Kikuyu, Brit. East Africa, collected by the Mission Gromier-Lepetit, July 9, 1911 ; ex Herb. Mus. Paris.

Pseudoleskea claviramea C. M. Table Mt., Cape Town, 1910 ; coll. H. A. W. (Nos. 18, 36) ; roots of trees and dry earth, Pretoria, 1910 ; coll. H. A. W. (Nos. 4, 22) ; Zululand, coll. Hobkirk, comm. G. Webster (No. 511) ; Van Reenen, 1917 ; coll. H. A. W. Mostly c. fr.

P. leskeoides (Schimp.) Broth. Grahamstown, C.P., coll. J. Burton, comm. G. Webster (Nos. 385, 505, 754) ; rock, Woodbush, Transvaal, 1910 ; coll. T. Jenkins, comm. W. Ingham (No. 2). I determine these from the description only ; no specimens are to be found in Schimper's Herbarium. There are a few old capsules only, on some.

P. Macowaniana C. M. Macomo's Hoek, 1897 ; coll. Mrs. Clarke Williams, comm. C. H. Binstead ; Moorddrift, Waterberg District, Transvaal, 1916 ; coll. H. A. W. (No. 403). Both c. fr. Mrs. Williams' specimen was sent me as *P. claviramea* C. M., determined, I believe, by Mitten, but the leaf arrangement alone precludes that. It differs from the previous species in the slightly more robust habit and larger cells, the leaf apex almost entire, and the perichaetial bracts longer and more aristate, sinuose-denticulate. These are just the characters by which C. Mueller distinguishes his *P. Macowaniana* from *P. leskeoides*, and I feel no hesitation, therefore, in referring the plants there, though with considerable doubt as to the value of the specific differences.

Thuidium versicolor (C. M.) Schimp. Hogsback, Tjumie, C.P., 1917 ; coll. D. Hend. (No. 337), c. fr.

Thuidium torrentium C. M. Maritzburg, 1906, and Barberton, Transvaal (No. 255b), 1914 ; coll. H. A. W. ; Kaapsche Hoop, Transvaal, 1915 ; coll. H. A. W. (No. 325) ; Rosehaugh, 3000 ft., Transvaal, Sept., 1914 ; coll. Sim (No. 8556) ; Pirie Forest, alt. 4000 ft., C.P., 1892 ; coll. Sim

(No. 7239); Hogsback, Tjumie, C.P., 1917; coll. D. Hend. (No. 335). All c. fr.

Thuidium sublaevipes Dixon sp. nov. (Pl. XII, fig. 16.)

T. laevipedi Mitt. affine; differt habitu *robustiore*, ramulis *minus complanatis*, foliis *siccis magis incurvo-crispatis*; seta *longiore*, usque ad 2.5 cm. longa (illius 1-1.5 cm.); theca *duplo fere majore*, longiore, 2 mm. longa, curvata, sicca vacua suberecta.

Hab.—Kaapsche Hoop, Transvaal, coll. H. A. W. (No. 295), c. fr.; Tjumie, 4-6000 ft., C.P., 1917; coll. D. Hend. (No. 358) c. fr.

Although near to *T. laevipes*, this is, I have no doubt, a different species, distinguished by the characters italicised above.

Thuidium promontorii C. M. Near Hogsback, 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 187); near Lovedale, C.P., 1913; coll. J. Henderson (No. 98); Pretoria, 1915; coll. Sim (No. 8558), c. fr.

HYPNACEAE.

Hygroamblystegium filicinum (L.) Loeske. Upper Bushman's River, 7000 ft., Natal, 1905; coll. Sim (No. 8670). Only a small quantity of this was sent, mixed with *Dicranella Symonsii* sp. nov. It is a very dwarf form, but cannot, I think, be separated in any way from our northern species, which have similar, and even smaller forms. It has not been hitherto recorded from South Africa. Distrib.: Europe, north to Spitzbergen, East, West and North Asia, North America, Algiers, New Zealand. *H. procerum* Dixon sp. nov., from Mt. Kenia, may perhaps be considered a subspecies.

Sciaromium Mitt. § LIMBIDIUM.

A genus of aquatic mosses having leaves of a very distinct structure, not hitherto represented in Africa; only one of the described species has yet been found in fruit. Most of the species belong to this section, distinguished by its leaves with very distinct, stout, thickened, entire border. They are nearly all confined to the subantarctic region of the southern hemisphere, or the higher mountains of S. America. The differences between the species are for the most part slight, and Cardot has expressed the doubt ('Flore Bryol. des Terres Magellaniques, &c.' p. 180) whether they are not mostly forms of a single species, *S. conspissatum* (Hook. f. & Wils.)—a view in which my examination of various species would lead me to concur. The present plant, however, differs from these species fully as markedly as most of them differ from one another, and for the present at least it must be treated as a new species.

Sciaromium capense Dixon sp. nov. (Pl. XII, fig. 17.)

Sat robustum, aquaticum, nigrum; caules circa 5 cm. longi, sicca rigidiusculi, madida molles, parce divisi, hic illic quoque breviter irregulariter ramulosi. Folia *dense conferta, haud vel viz secunda*, sicca madidaque

erecto-patentia, 1.5-1.75 mm. longa, e basi oblongo-ovata in acumen robustissimum saepius leniter curvatum subacutum angustata. Costa crassissima, prope basin circa 120 μ lata, supra paullo angustata, basin versus acuminis cum limbis subaequilatis valde crassis confluentis, unde totam fere acumen incrassatum, omnino opacum cartilagineum fit.

Cellulae laminae ellipticae vel rhomboideae, incrassatae, irregulares, 5-6 μ latae, circa duplo longiores quam latae; inferne sensim elongatae, rhomboideo-lineares. Cetera ignota.

Hab.—Near Hogsback, alt. 4-6000 ft., Tjumie, C.P., 1916; coll. D., B. & M. Hend. (No. 213).

Among the species hitherto described of this section, I have not found any with the leaf form and structure corresponding at all closely to this. Most of them are much larger plants, with leaves less closely imbricate, usually larger and often strongly falcate; while those with the size and same foliar arrangement as this have the border and nerve less strongly developed, and especially the nerve excurrent into a comparatively short, cuspidate point. Here the borders and nerve are so stout that frequently their combined width is equal to that of the rest of the lamina in its widest portion, while the same cause leads to their union close to the base of the acumen, and the nerve is properly speaking excurrent from that point; in other words the very stout acumen, forming something like half the length of the leaf, is practically composed almost entirely of the excurrent nerve.

It is a most interesting addition to the S. African flora.

Two or three species formerly referred to *Sciaromium*, from the West African Islands, are of quite a different character, and are now placed in *Echinodium*—a very distinct genus.

Microthamnium ctenidioides Dixon sp. nov. (Pl. XII, fig. 18.)

§ PSEUDO-MICROTHAMNIUM. *Gracillimum*; caulis primarius filiformis, repens, irregulariter distanter subpinnatus, ramis nonnunquam iterum ramulosus; folia sicca madidaque horride patentia, luteo-viridia, subnitida, haud complanata, e basi ovato-cordata, amplexicauli, longiuscule argute acuminata, superne integerrima, inferne saepe minute denticulata; costa brevissima, gemella; cellulae superiores medianae lineares vel fusiformes, marginem versus breviores, rhomboideo-lineares, sigmatoideae, omnes pellucidae, dorso laeves; alares sat numerosae, irregulariter subquadratae, magis opacae. Autoicum. Folia perichaetialia suberecta, longe angustissime subulata, seta 1 cm., vel paullo ultra, tenuis; calyptra nuda; theca parva, inclinata, curvata, operculo conico, obtuso.

Hab.—Near Hogsback, alt. 4-6000 ft., Tjumie, C.P., 1916; coll. D. B. & M. Hend. (No. 220).

This is a slender species, with stellately spreading leaves, in habit resembling some *Ctenidia*; *M. horridulum* Broth., from Pondoland, is near

it, but has more shortly pointed leaves wider at base. (*M. Shawii* Rehm. ined. is very similar to *M. horridulum*, if indeed distinct from it.) *Ctenidium squarriifolium* (C. M.) from the Cameroons is much like it, but is dioicous. The autoicous inflorescence is the principal argument, perhaps, for placing this present species in *Microthamnium*, some other species of which also are very closely related to species of *Ctenidium*.

M. patens (Hampe) Jaeg. Barberton, Transvaal, 1914; coll. H. A. W. (No. 252), c. fr.

M. cygnicollum (Hampe) C. M. Kaapsche Hoop, 6000 ft., Transvaal, 1915; coll. H. A. W. (No. 294), c. fr.; near Hogsback, 4-6000 ft., Tjume, C.P., 1916; coll. Hend. (No. 219), c. fr.

M. pseudo-reptans C. M. Kaapsche Hoop, 1915; coll. H. A. W. (No. 329 p.p.), c. fr.

M. cavifolium (Rehm.) Dixon. Kaapsche Hoop, 1915; coll. H. A. W. (Nos. 293, 316, 318), c. fr.

Stereodon aduncoides (C. M.) Broth. Knysna Forest, C.P.; coll. W. C. Worsdell (No. 7). Agrees quite well with the Bourbon plant; the single row of marginal basal cells, wide and hyaline, is characteristic. Hitherto recorded from Bourbon and Madagascar.

Isopterygium brachycarpum Dixon sp. nov. (Pl. XII, fig. 19.)

Caules dense intertexti, caespites densos, *saturate vel lacte virides* nitidos formantes, plus minus conferte ramosi, ramis brevibus, obtusis. Folia subcomplanata, late patentia, saepius falcato-secunda, e basi coarctata late ovato-oblonga, *breviter acutissime acuminata*, concava, apice integra vel obscure denticulata, costa brevissima, gemella; folia ramea brevius acuminata vel tantum acuta; cellulae *peranguste lineares, vermiculatae*, 5-6 latae, apicem basinque versus paullo latiores, alares 2-4, *majusculae, vesiculosae, hyalinae*, supra-alares perpaucae, irregulariter subquadratae.

Autoicum. Perichaetium breve, foliis acumine breviter subulato, integro, internis erectis, in acumen breviter loriforme flexuosum subsquarrosus *abrupte coarctatis, basin versus acuminis saepius irregulariter grossiuscule 2-3-dentatis*. Seta tenuis, *vix 1 cm. alta*; theca parva, *brevis, elliptica*, collo *vix ullo*; operculum conico-rostellatum, curvatum.

Hab.—Knysna, C.P., coll. H. A. W. (No. 512); Rietfontein, Transvaal, coll. H. A. W. (No. 234).

Distinct from the previously described African species, especially in the short, thin seta, small, elliptical capsule, passing abruptly at the base into the seta; and markedly in the inner perichaetial bracts, which nearly always have a striking toothed somewhat similar to that in *Plagiothecium Miquelii* from the East Indies (*cf.* fig. XII).

No. 234 was sent as "*Plagiothecium subrhynchostegioides* Broth. & Wager n. sp., Broth. in litt. ad H. A. Wager." I find it, however, to be identical with the previously sent plant which I had already reported and

distributed as *I. brachycarpum*. I have therefore retained that name. Both on account of the scarcely enlarged, not decurrent basal cells (except for the small group of two or three hyaline ones), and on account of the undoubted affinity with *I. Dubyi*, *I. Welwitschii*, *I. strangulatum*, etc., I think it must be placed in *Isopterygium*.

It resembles *Plag. rhynchostegioides* C. M., but is a much smaller plant altogether in all its parts. *I. Welwitschii* Gepp resembles it, but apart from the perichaetial leaves has more gradually tapering, longer leaf-points, a longer seta, etc. *I. Antunesii* Broth. is larger, with sharply denticulate leaf-points, and a different capsule. *I. Dubyi* Gepp has the same character of perichaetial bracts, but is a far more robust plant, larger in all its parts, with much wider leaf-cells.

I. strangulatum Hampe also resembles it, but is larger, and has wider areolation, and is without the enlarged alar cells.

Plagiothecium Hendersonii Dixon, sp. nov. (Pl. XII, fig. 20.)

Sat *robustum*, *praevitens*, *laetevirens*; caulis repens, irregulariter ramosus, ramis brevibus, foliis *complanato-decurvis*. Folia 1.5–2 mm. longa, late oblongo-lanceolata, *breviter late acuminata*, concava, apice subdenticulato, marginibus erectis, basi subdecurrentia; costa gemella, brevissima vel nulla; cellulae *angustae*, 5–7 μ latae, elongatae, valde prosenchymaticae, parietibus angustis, firmis, basin versus sensim latiores, infimae 10–13 μ latae, parietibus incrassatis, porosis; alares *numerosae, magnae, regulariter subquadratae, perpellucidae*.

Autoicum. Perichaetia circa 3 mm. longa, foliis externis subsquarrosis, internis suberectis, omnibus in acumen longum subulatum integrum vel subintegrum productis. Cetera ignota.

Hab.—Hogsback, Tjumie, C.P., alt. 4–6000 ft., 1917; coll. D. Henderson (Nos. 366, 365).

Only young setae were found. A quite distinct species, with habit perhaps most nearly that of *P. denticulatum* (L.), but with much narrower upper areolation, and very numerous, subquadrate alar cells. *P. rhynchostegioides* C. M. differs in the smaller size, the finely acuminate points of the leaves, the basal cells little enlarged, the perichaetial leaves with very long capillary subula. *P. selaginelloides* C. M. and *P. membranosulum* C. M. have laxer, quite different areolation.

Catagonium macronotum (C. M.) Broth. George, C.P., 1916; coll. H. A. W. (Nos. 502, 503), c. fr.; near Hogsback, Tjumie, 4–6000 ft., 1916; coll. Hend. (No. 201a).

Vesicularia sphaerocarpa (C. M.) Broth. Barberton, Transvaal, 1914; coll. H. A. W. (Nos. 256, 259), c. fr.; Mossel R., C.P., 1913; coll. Prof. G. Potts, comm. Sim (No. 24); Pinetown, New Germany, 1000 ft., Natal, 1917; coll. P. van der Bijl, comm. Sim (No. 8680), c. fr.; Knysna, C.P., 1700 ft., coll. J. Burt-Davy, comm. Sim (No. 8679). Mr. Sim writes

that he finds the variability of the leaf apex very great, but extremes sometimes occur on the same plant, the vigorous young shoots having long denticulate leaf apex, while the slower growth has the more obtuse, entire apex; also that the variation in cell width to some extent corresponds, the long and slightly falcate leaves having usually longer cells. These observations agree entirely with my own experience. In any tuft of the plant placed under the microscope one generally finds a certain number of leaves with short, wide points, not falcate, while other branches have longly acuminate, falcate-decurved leaves; in the former the cells are very wide and short, giving the leaf a strikingly reticulate appearance; in the other form the cells are more chlorophyllose, longer and narrower, and much more difficult to restore when moistened; in fact the apparent narrowness of the cells is to some extent at least due to their failure to expand under moistening. I believe that a certain number, at least, of the species of *Vesicularia* described from S. Africa are based solely on the above variations of characters, and actually should be placed under *V. sphaerocarpa*. It is at any rate widely distributed over the African continent and the East African Archipelago.

SEMATOPHYLLACEAE.

Rhaphidostegium.

Some of the African species of this genus, belonging to the § *Cupressinopsis*, offer great difficulties, which I have not at present been able to clear up. The difficulty is enhanced by the fact that C. Mueller's description of *R. Dregei* does not at all agree in some particulars with specimens under that name in our collections, although some of them at least were presumably determined by C. Mueller himself. Thus C. Mueller describes the leaves as *very narrowly lanceolate*, laying great stress on this character, whereas Rehmann's No. 411b, as well as Breutel's specimens at Kew, show them decidedly broadly lanceolate. He also describes the perichaetial leaves as "longissime subfiliformi-acuminata," while in Rehmann's plant they are acute, but rigidly, by no means longly or narrowly acuminate. It is possible that the plants are not correctly determined. They appear to agree well with C. Mueller's description of *R. dentigerum*, which I have not been able to see. *R. krakammae* (C. M.), of which I have examined original specimens in Hampe's Herbarium, I am inclined to think is only a rather small form of *R. Dregei*. In any case *R. tapeinophyllum* (C. M.) is, I have no doubt, identical with *R. Dregei*. All these plants have the upper cells more or less papillose at back.

R. Gueinzii (C. M.) is another perplexing species; the cuspidate branch tips do not appear to afford a constant character. I am inclined to think the perichaetial bracts give the best guide; they are wide and very shortly pointed, even subobtuse, and *very closely* denticulate, in the upper part; I

suspect, indeed, that the form of the perichaetial bracts is of first importance in the determination of some of these plants, and must be held to outweigh considerable differences in the leaf form and disposition. A plant collected by Prof. Wager at Montagu Pass (No. 575), however, with the characteristic perichaetial bracts of *R. Gueinzii*, has a very different foliation from usual, and has, moreover, a distinctly stouter seta than typical *R. Gueinzii*.

I have therefore not ventured to record the various plants received of this group until further light has been thrown upon them.

R. hyalotis (C. M.) Par. Knysna, C.P., 1916; coll. H. A. W. (No. 508), c. fr.; Kaapsche Hoop, Transvaal, 6000 ft., 1915; coll. H. A. W. (No. 292), c. fr.

R. brachycarpum (Hampe) Jaeg. Grahamstown, C.P., 1910; coll. J. Hewitt, comm. W. Ingham (No. 7); Barberton, Transvaal, 1914-15; coll. H. A. W. (Nos. 266, 280); Kaapsche Hoop on wood and on earth, 1915; coll. H. A. W. (Nos. 308, 309); Knysna, C.P., 1916; coll. H. A. W. (No. 513); George, C.P., 1916; coll. H. A. W. (Nos. 501, 555). Mostly c. fr.

R. sphaeropyxis (Rehm.) Par. George, C.P., 1916; coll. H. A. W. (No. 534), c. fr. Agrees quite well with Rehm's plant at Kew. C. Mueller's description of the seta as "semipollicaris" is not very exact; it is less than 1 cm. in length.

R. sphaerocarpa (C. M.) Jaeg. I have had this frequent and eminently variable species sent from various parts of S. Africa, ranging from Cape Town to Salisbury in Rhodesia.

BRACHYTHECIACEAE.

Pleuropus sericeus (Hornsch.) Broth. Grahamstown, C.P., coll. J. Burton, comm. G. Webster (No. 347); Pirie Forest, 4000 ft., C.P., 1892; coll. Sim (No. 7154).

Var. *afro-striatus* (C. M.). Knysna, C.P., 1916; coll. H. A. W. (Nos. 515, 523), c. fr.; near Hogsback, 4-6000 ft., Tjumie, C.P., 1916; coll. Hend. (No. 188).

Brachythecium implicatum (Hornsch.) Jaeg. (syn. *B. afro-salebrosum* C. M.; *B. afro-velutinum* C. M.; *B. Knysnae* C. M.; *B. Dicksoni* Rehm. M. Austr.-Afr. No. 383). Near Lovedale, C.P.; coll. Rev. J. Henderson, comm. Rev. D. Lillie (No. 97); Knysna Forest, C.P., 1914; coll. W. C. Wordsell (No. 8); Kaapsche Hoop, Transvaal.

Brachythecium afro-albicans Dixon, sp. nov. (Pl. XII, fig. 21.)

Habitu *B. albicantis* (L.), sed gracilius, foliis minoribus. Stramineus. Caules, ut videtur, erecti, paralleli, hic illic radiculosi, usque ad 8 cm. alti, graciles, molles, irregulariter distanter subpinnatim ramosi; folia *suberecta*, *sicca appressa*, *julacea*. Folia caulina leviter plicata vel tantum concava,

ovato-lanceolata, marginibus planis vel uno latere prope basin angustissime reflexo, *breviter acutissime acuminata, integra*; costa circa $\frac{2}{3}$ folii longitudinem attingens, superne tenuis, *basin versus multo dilatata*, 50–70 μ lata. Rete superior pellucida, e cellulis rhomboideo-linearibus prosenchymaticis, circa 8 μ latis instructum, cellulae basiliares *per totam folii latitudinem seriebus multis abrupte dilatatae, magnae, pellucidae, subquadratae vel transverse compressae, valde conspicuae*.

Dioicum videtur. Flores unisexuales, femineae *minimae, gemmiformes*, bracteis *brevissimis, ovatis, acutis*, archegoniis circa 6, parvis, plus minus 150 μ longis, bene evolutis.

Hab.—Blinkwater Ravine, Table Mt., C.P., 1917; coll. Prof. Bews, comm. Sim (No. 8634).

A remarkable species, resembling *B. albicans* (L.) in habit, but with smaller, scarcely plicate leaves, having a very striking basal areolation. The lax, pellucid, subquadrate alar cells are abruptly differentiated from the upper areolation, reach rather high in the leaf, and not only extend to the nerve but cover its ventral surface for some little distance above the insertion.

The flowers are very unusual, if not abnormal. I have dissected out several and find them all uniform; they are very minute in size, position and appearance, precisely as one would expect to find the male flowers, and with the bracts corresponding to the usual structure in these; but they all contain archegonia, small, but fully developed, deep red, and with every appearance of being normal. It would be very desirable to collect fruiting plants of this species.

Brachythecium pinnatum Dixon, sp. nov. (Pl. XII, fig. 22.)

Subrobustum; caules elongati, 5 cm. et ultra longi, repentes, plus minusve dense, *sat regulariter pinnati*, ramis *subaequalibus*, circa 5–7 mm. longis, *flexuosis, gracilibus, myuroideis, acutis*. Folia juniora laete virentia, nitentia, senectute fuscescentia; circa 2 mm. longa; caulina e basi *late deltoideo-cordata cito in acumen longum reflexum tenuissime acuminatum*, subintegrum angustata, costa tenui ad acuminis basin accedente, cellulis *angustissime linearibus*, basilaribus laxiusculis, alaribus sat numerosis, isodiametricis, parvis, subobscuris. Folia ramea multo angustiora, late oblonga, *latius brevius acuminata, apice dentata, longitudinaliter plicata*.

Dioicum. Planta mascula floribus multis, caule sitis, *sat magnis*, bracteis numerosis *stellate patentibus*, late ovatis *longe stricte acuminatis*, internis (2–3) tantum minoribus, ovatis, breviter acutis; antheridia numerosa. Folia perichaetalia multa, intima e basi elongata *cito in acumen longum subfiliforme potens subdenticulatum coarctata, marginibus apud basin acuminis dentibus pluribus subfimbriatis praeditis*. Seta circa 1 cm. alta, laevis, atro-rubens. Theca subhorizontalis, anguste breviter cylindrica, gibbosa, curvata, operculo breviter rostellato, *perobtusio*.

Hab.—Knysna, C.P., coll. H. A. W. (No. 520).

Quite distinct from the other S. African species of the genus, in the densely pinnate branching combined with the peculiarly toothed perichaetial leaves. *B. pseudo-populeum* (Schimp.) C. M., the description of which reads much like this, is really very distinct, being much smaller, with closer, much smaller and narrower leaves, shorter seta, short oval capsules with conical lid, etc.

B. stricto-patens C. M. Grahamstown, C.P., comm. G. Webster (No. 773), c. fr. This agrees with C. Mueller's description; no specimens are in the Kew or British Museum collections, and I have not been able to compare it.

B. plumosiforme Schimp. Hout Bay, C.P., 1916; coll. H. A. W. (No. 601), c. fr.; Hogsback, Tjummie, C.P., 1917; coll. D. Hend. (No. 360), c. fr. No. 601 is a smaller plant in all its parts than the type plant in Schimper's collection, but the species varies considerably in form and direction of capsule, and also in the perichaetial leaves.

Rhynchostegium brachypterum (Hornsch.) Jaeg. Knysna, and George, C.P., 1916; coll. H. A. W. (Nos. 521, 544), c. fr.; Kowie, C.P., 1915; coll. H. A. W. (No. 115), c. fr. Another very variable plant, in form of leaves, length and toothings of acumen, and form of capsule.

EXPLANATION OF PLATES XI AND XII.

PLATE XI.

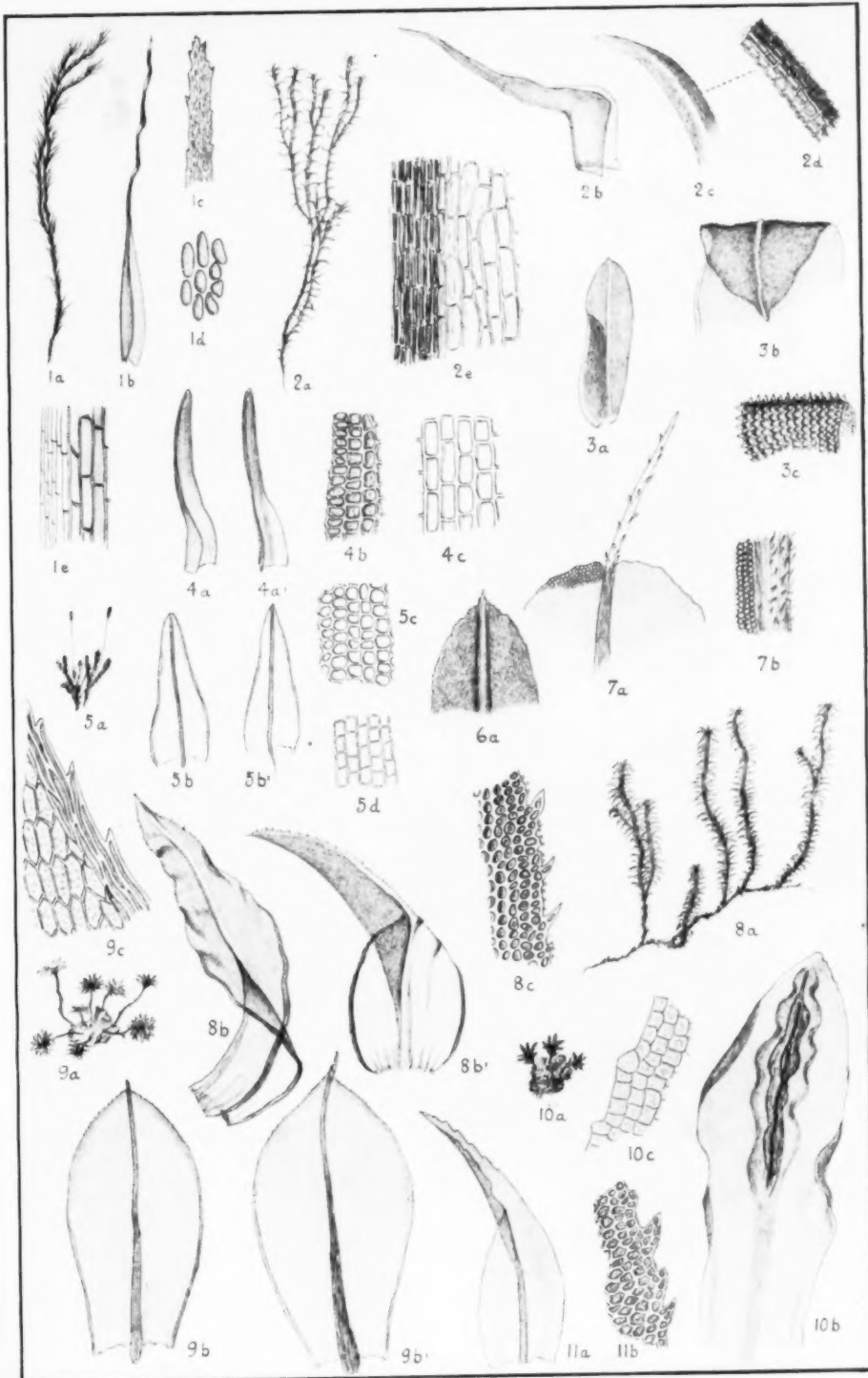
FIG.

1. *Ditrichum spirale*. (a) Plant, $\times 1$; (b) leaf, dry, $\times 10$; (c) apex of leaf, $\times 50$; (d) upper cells of sheathing part, $\times 200$; (e) supra-basal marginal cells, $\times 200$.
2. *Dicranella Symonsii*. (a) Plant, $\times 1$; (b) leaf, $\times 20$; (c) leaf-apex, $\times 50$; (d) upper cells, $\times 200$; (e) basal cells (with half nerve), $\times 200$.
3. *Fissidens papillifolius*. (a) Leaf, $\times 20$; (b) leaf apex, $\times 50$; (c) upper and marginal cells, $\times 200$.
4. *Gymnostomum Bensii*. (a, a') Leaves, $\times 20$; (b) upper marginal cells, $\times 200$; (c) basal cells, $\times 200$.
5. *Didymodon Pottsii*. (a) Plant, $\times 1$; (b, b') leaves, $\times 20$; (c) upper cells, $\times 200$; (d) basal cells, $\times 200$.
6. *Didymodon afro-rubellus* (dup. type). (a) Leaf apex, $\times 40$.
7. *Tortula trachyneura*. (a) Leaf apex, $\times 40$; (b) back of nerve, $\times 100$.
8. *Zygodon Simii*. (a) Stem, $\times 1$; (b, b') leaves, $\times 20$; (c) upper cells, $\times 200$.
9. *Bryum pumili-roseum*. (a) Plant, $\times 1$; (b, b') leaves, $\times 20$; (c) upper cells, $\times 200$.
10. *Psilopilum afro-laevigatum*. (a) Plant, $\times 1$; (b) leaf, $\times 20$; (c) upper cells, $\times 200$.
11. (Rehm. M.A.-A., No. 150) *Zygodon runcinatus*. (a) Leaf, $\times 20$; (b) upper cells, $\times 200$.

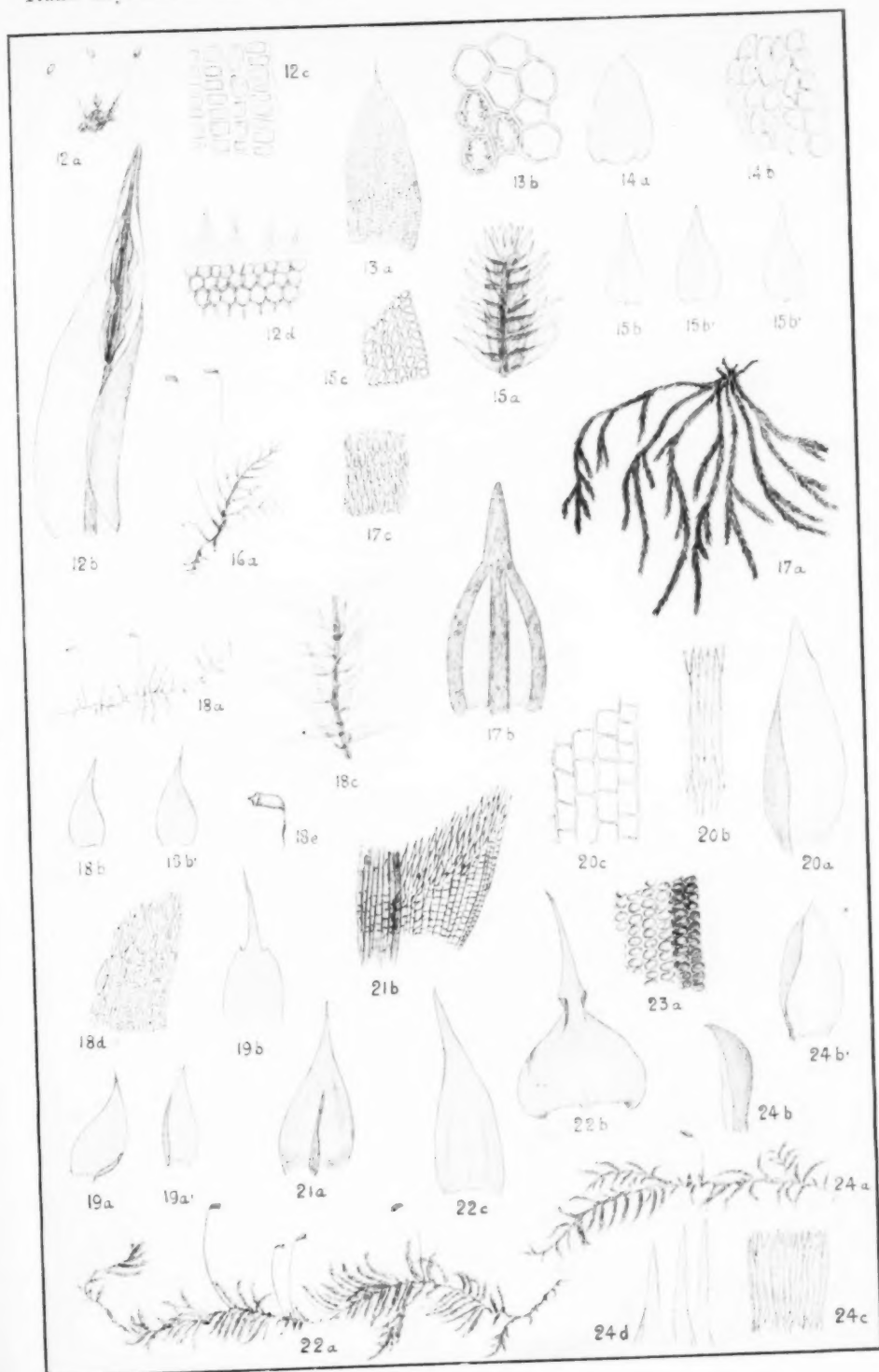
PLATE XII.

12. *Psilopilum Wageri* (dup. type). (a) Plant, $\times 1$; (b) leaf, $\times 20$; (c) upper marginal cells, $\times 200$; (d) peristome teeth, $\times 100$.

13. *Erpodium transvaaliense* (dup. type). (a) Leaf, $\times 20$; (b) upper cells, $\times 200$.
14. *Erpodium distichum*. (a) Leaf, $\times 20$; (b) upper cells, $\times 200$.
15. *Lindbergia viridis*. (a) Part of branch, $\times 20$; (b) leaves, $\times 20$; (c) upper cells, $\times 200$.
16. *Thuidium sublaevipes*. (a) Stem, $\times 1$.
17. *Sciaronium capense*. (a) Plant, $\times 1$; (b) leaf, $\times 10$; (c) upper cells, $\times 200$.
18. *Microthamnium stenidioides*. (a) Stem, $\times 1$; (b, b') leaves, $\times 20$; (c) part of branch, $\times 20$; (d) alar cells, $\times 200$; (e) capsule, $\times 6$.
19. *Isopterygium brachycarpum*. (a, a') Leaves, $\times 20$; (b) inner perichaetial leaf, $\times 20$.
20. *Plagiothecium Hendersonii*. (a) Leaf, $\times 20$; (b) upper, (c) alar cells, $\times 200$.
21. *Brachythecium afro-albicans*. (a) Leaf, $\times 20$; (b) basal cells, $\times 100$.
22. *Brachythecium pinnatum*. (a) Stem, $\times 1$; (b) stem leaf, $\times 20$; (c) branch leaf, $\times 20$.
23. *Glyphomitrium marginatum*. (a) Upper cells, $\times 200$.
24. *Entodon cymbifolius*. (a) Stem, $\times 1$; (b, b') branch leaves, $\times 20$; (c) upper cells, $\times 200$; (d) apex of perichaetial leaves, $\times 20$.



S. African Mosses.



S. African Mosses.

COLOUR AND CHEMICAL CONSTITUTION.

PART IX.—AN EMPIRICAL LAW OF CHANGE OF COLOUR.

BY JAMES MOIR, M.A., D.Sc., F.I.C.

In Part I of this series (March, 1917) it was pointed out that the change of colour caused in phthaleins and fluoresceins by the introduction of substituting groups is not explicable in terms of the atomic weight—for example, tetrabromo- and tetriodo-phenolphthalein are very nearly the same in spectrum.

A special investigation of the halogen-derivatives of the two parent-substances has now shown that the laws connecting the change of colour with the number and nature of the halogen substituents are quite simple and regular, with the result that the whole of the experimental results can be calculated (and the spectrum of unknown substances predicted) from a single simple algebraical formula. This formula is:

$$\frac{n}{n_0} = 1 - \frac{m}{100} (1.15 + 0.0037 N),$$

in which n is the frequency ($1/\lambda$) of the halogenated derivative, n_0 the frequency of the parent-substance (18.05 for phenolphthalein and 20.27 for fluorescein), m the number of halogens, and N the atomic number of the halogen (17 for Cl, 35 for Br, and 53 for I). The table on p. 226 exhibits the close agreement between theory and observation.

An examination of the algebraical formula shows that the factor involving the atomic number is small; if we neglect it we arrive at the additive law enunciated in the previous sections of this work, addition of wave-length being the same as subtraction of frequency. It is very important to note that the formula holds for fluorescein derivatives as well as for phthaleins.

In the case of the dihalogen-derivatives, two isomers are possible and were made and examined. The observation marked (*a*) in each case refers to the 2-2' derivative,* in which each phenol ring contains one chlorine (or bromine) atom, while that marked (*b*) refers to the 2-6 derivative, in which both halogens are in the same ring, the other phenol ring being unhalogenated. The 2-2' derivative is obtained either from phthalic acid and

* The hydroxyl is counted as 1 in the numbering.

orthochlorophenol, or by cautious chlorination of phenolphthalein in cold dilute alcohol. The 2-6 derivative is obtained either from *p*-oxybenzoylbenzoic acid and 2-6 dichlorophenol, or from phenol with 3-5 dichloro-4-oxybenzoylbenzoic acid,* the latter substance being obtained by splitting tetrachloro-phenolphthalein with hydroxylamine in the same way as *p*-oxybenzoylbenzoic acid is obtained from phenolphthalein (see Part II).

Only one *o*-trichloro-phenolphthalein can exist; this has not been made but its absorption-band is predicted to be at λ 576.

TABLE A.

| Name of coloured substance. | Spectrum centre of absorption band. | Value of m . | Value of N . | Calculated frequency. | Calculated λ . |
|---------------------------------------|--|--|---|-----------------------|------------------------|
| Tetrachloro-phenolphthalein . | λ 583 | 4 | 17 | 17.15 | 583 |
| Tetrabromo- " . | λ 584 | 4 | 35 | 17.11 | 584 $\frac{1}{2}$ |
| Tetrido- " . | λ 586 | 4 | 53 | 17.07 | 585 $\frac{1}{2}$ |
| Tetrachloro-fluorescein . | λ 519 | 4 | 17 | 19.26 | 519 |
| Tetrabromo- " (eosin) . | λ 521 | 4 | 35 | 19.21 | 520 $\frac{1}{2}$ |
| Tetrido- " (erythrosin) . | λ 523 | 4 | 53 | 19.16 | 522 |
| <i>o</i> -dibromo-phenolphthalein . | $\left\{ \begin{array}{l} \lambda 569 (a) \\ \lambda 570 (b) \end{array} \right\}$ | 2 | 35 | 17.60 | 569 |
| 2.2' dibromo-fluorescein . | λ 508 | 2 | 35 | 19.73 | 506 $\frac{1}{2}$ |
| <i>o</i> -Monochloro-phenolphthalein. | λ 560 | 1 | 17 | 17.84 | 561 |
| <i>o</i> -Dichloro-phenolphthalein . | $\left\{ \begin{array}{l} \lambda 570 (a) \\ \lambda 569 (b) \end{array} \right\}$ | 2 | 17 | 17.62 | 568 |
| 2.6 dibromo-2' methyl derivative . | λ 573 | 2 | 35 | 17.35† | 576 |
| 2.6 dibromo-3' methyl derivative . | λ 584 | 2 | 35 | 17.12‡ | 584 |
| [Tetrido-tetrachloro-fluorescein . | λ 548§ | $\left\{ \begin{array}{l} 4 \\ 4 \end{array} \right\}$ | $\left\{ \begin{array}{l} 17 \text{ plus} \\ 53 \end{array} \right\}$ | 18.16 | 550] |

Of the isomeric dihalogen derivatives it may be noted that the 2-6 variety is easily bleached by excess alkali, whereas the 2-2' variety resists alkali to some extent.

On perchlorination of phenolphthalein in warm chloroform solution a small quantity of a product giving an emerald-green solution in alkali was obtained. The central wave-length of the band was λ 642, from which it may be inferred that it is probably decachloro-phenolphthalein. The

* This substance gives an orange-coloured solution in strong sulphuric acid, with an absorption-band at λ 472.

† Calculated from 17.80, the frequency of phenolortho-cresolphthalein.

‡ " " " 17.57 " " phenolmeta-cresolphthalein.

§ Taken from 'Chemiker Kalender'; not personally observed.

following data may be noted about the behaviour of these new halogenated phthaleins when dissolved in concentrated H_2SO_4 and spectroscoped. Under these conditions phenolphthalein gives a band with centre at about λ 499 (orange solution). The solutions of the halogen-derivatives are of various shades of salmon-pink and have the following central wave-lengths:

| | |
|--|---------------|
| 2 monochloro-compound | λ 502 |
| 2-6 dichloro- " | λ 505 |
| 2-6 dibromo. " | λ 506 |
| 2-6 dibromo-2' methyl compound | λ 511 |
| 2-6 dibromo-3' methyl " | λ 521 |
| 2-6-2'-6' tetrachloro " | λ 530 |

Although the formula for the halogenated colours is merely empirical—in the sense of lacking for the present a physical basis of explanation—it is obviously worth while seeing to what extent it applies to derivatives of phenolphthalein and fluorescein which are *not* halogenated. For this purpose such groups as methyl and isopropyl may be taken to have molecular numbers made up of the atomic numbers (1 for hydrogen and 6 for carbon)—viz. 9 and 25 respectively. On this basis ortho-monomethyl-phenolphthalein should have a frequency of 18.05 ($1 - 0.01183$), corresponding to wave-length λ 561, and the observed wave-length is λ 562 (the other name of the substance being phenolortho-cresolphthalein). In the same way ortho-dimethyl-phenolphthalein (*o*-cresolphthalein) is calculated to have a frequency of 18.05 ($1 - 0.02366$), corresponding to wave-length λ 568, observation giving λ 570.

If, further, we make the assumption (adumbrated in Part I of this series) that the meta-position has *twice the effect* of the ortho-position, the calculated value for phenolmetacresolphthalein is λ 568, and that for metacresolphthalein (metadimethyl-phenolphthalein) is λ 582. Observation gave λ 569 and λ 584 respectively.

In the same way phenol-thymolphthalein, which has one metamethyl and one orthoisopropyl group, should have the frequency 18.05 ($1 - 2 \times .01183 - .01242$), corresponding to λ 575; observation gave λ 578. Thymolphthalein should similarly give 18.05 ($1 - .0722$), corresponding to λ 597, which agrees precisely with observation. Again, phenol-carvaerolphthalein, which has one orthomethyl and one metaisopropyl group, should have the frequency 18.05 ($1 - .01183 - 2 \times .01242$), corresponding to λ 575½; observation gave λ 580. So for carvaerolphthalein the calculated value is λ 598 and observation λ 601.

It is evident that the law is approximately true for all these varied and rather complicated derivatives, but equally evident that the agreement is not good enough and that the formula requires a small correction to make

it fit all the observations within the experimental error, which is usually not more than one unit in the wave-length reading.

In any case, my theory in Part I, that it is molecular volume that is the main factor in colour-change, must be abandoned. It is obvious that when such different groups as methyl, isopropyl, chlorine, bromine and iodine produce almost the same effect, the explanation must be of an unusual character. The only thing these groups have in common is monovalency or an electron, but this is common to all groups substituting a benzene ring in the ordinary manner, and is therefore not in itself characteristic enough for an explanation.

ADDITIONAL NOTE ON THE RESOLVABILITY OF THE MINORS OF A COMPOUND DETERMINANT.

BY SIR THOMAS MUIR, LL.D.

(1) One way in which compound determinants arise naturally in the course of work is in connection with the simple matter of elimination in the case of a set of homogeneous linear equations when the elimination is effected by what we may call the method of instalments. For example, if our set of equations be

$$\left. \begin{aligned} a_1 u + a_2 v + a_3 w + a_4 x + a_5 y + a_6 z &= 0 \\ b_1 u + b_2 v + b_3 w + b_4 x + b_5 y + b_6 z &= 0 \\ . &. \\ f_1 u + f_2 v + f_3 w + f_4 x + f_5 y + f_6 z &= 0 \end{aligned} \right\}$$

we may as a first step eliminate u and v , obtaining thus 20 equations of the type

$$\begin{vmatrix} a_1 & a_2 & a_3w + a_4x + a_5y + a_6z \\ b_1 & b_2 & b_3w + b_4x + b_5y + b_6z \\ c_1 & c_2 & c_3w + c_4x + c_5y + c_6z \end{vmatrix} = 0,$$

 $i, e.$

$$|a_1 b_3 c_3| w + |a_1 b_3 c_4| x + |a_1 b_3 c_5| y + |a_1 b_3 c_6| z = 0;$$

and then taking four of this derived set eliminate the remaining unknowns, and so arrive at the desired resultant in a form of the type

| | | | |
|---------------|---------------|---------------|---------------|
| $a_1 b_2 c_3$ | $a_1 b_2 c_4$ | $a_1 b_2 c_5$ | $a_1 b_2 c_6$ |
| $a_1 b_2 d_3$ | $a_1 b_2 d_4$ | $a_1 b_2 d_5$ | $a_1 b_2 d_6$ |
| $a_1 b_2 e_3$ | $a_1 b_2 e_4$ | $a_1 b_2 e_5$ | $a_1 b_2 e_6$ |
| $a_1 b_2 f_3$ | $a_1 b_2 f_4$ | $a_1 b_2 f_5$ | $a_1 b_2 f_6$ |

(2) Such a determinant is readily seen to be a minor of the compound of the determinant of the original set of equations; for example, the resultant just reached is a 4-line minor of the 3rd compound of $|a_1b_2c_3d_4e_5f_6|$. Now the true resultant being known to be the said determinant of the original set, it follows that the compound determinant obtained by the method of instalments must in general contain the true resultant as a factor. This simple observation is of considerable value in connection with the problem of the factorisation of the minors of a compound, the reason being equally

In the case of *three* letters the determinant is simply an adjugate. We have, for example,

$$\begin{vmatrix} |e_5 f_6| & |e_4 f_6| & |e_4 f_5| \\ |d_5 f_6| & |d_4 f_6| & |d_4 f_5| \\ |d_5 e_6| & |d_4 e_6| & |d_4 e_5| \end{vmatrix} = |d_4 e_5 f_6|^2,$$

whence by taking complementaries we deduce the desired factorisation—

$$\begin{vmatrix} |a_1 b_2 c_3 d_4| & |a_1 b_2 c_3 d_5| & |a_1 b_2 c_3 d_6| \\ |a_1 b_2 c_3 e_4| & |a_1 b_2 c_3 e_5| & |a_1 b_2 c_3 e_6| \\ |a_1 b_2 c_3 f_4| & |a_1 b_2 c_3 f_5| & |a_1 b_2 c_3 f_6| \end{vmatrix} = |a_1 b_2 c_3|^2 \cdot \Delta_6,$$

where Δ_6 is written for $|a_1 b_2 c_3 d_4 e_5 f_6|$.

The number of instances of this type of resolvability is manifestly $C_{6,3}$, i. e. 20.

(6) In the case of *four* letters it is necessary to make a subdivision. In the first place we have to consider the type

$$\begin{vmatrix} |e_5 f_6| & |e_4 f_6| & |e_4 f_5| \\ |d_5 f_6| & |d_4 f_6| & |d_4 f_5| \\ |e_5 f_6| & |e_4 f_6| & |e_4 f_5| \end{vmatrix}$$

in which the four letters are so distributed that a selected one of the four appears in every row. Here the determinant vanishes, and the Law of Complementaries consequently gives us

$$\begin{vmatrix} |a_1 b_2 c_3 d_4| & |a_1 b_2 c_3 d_5| & |a_1 b_2 c_3 d_6| \\ |a_1 b_2 c_3 e_4| & |a_1 b_2 c_3 e_5| & |a_1 b_2 c_3 e_6| \\ |a_1 b_2 d_3 e_4| & |a_1 b_2 d_3 e_5| & |a_1 b_2 d_3 e_6| \end{vmatrix} = 0,$$

the number of instances of the type being

$$C_{6,4} \times 4, \text{ i. e. } 60.$$

In the next place we have to consider auxiliaries such as

$$\begin{vmatrix} |e_5 f_6| & |e_4 f_6| & |e_4 f_5| \\ |d_5 f_6| & |d_4 f_6| & |d_4 f_5| \\ |e_5 e_6| & |e_4 e_6| & |e_4 e_5| \end{vmatrix}, \quad \begin{vmatrix} |e_5 f_6| & |e_4 f_6| & |e_4 f_5| \\ |e_5 f_6| & |e_4 f_6| & |e_4 f_5| \\ |d_5 e_6| & |d_4 e_6| & |d_4 e_5| \end{vmatrix},$$

in which each of two letters, *e* and *f* say, occurs twice, and the other two, *e* and *d* say, each once. The factorisation for both of these is the same—a fact worthy of separate note—namely,

$$|d_4 e_5 f_6| \cdot |e_4 e_5 f_6|;$$

and consequently we have

$$\begin{vmatrix} |a_1 b_2 c_3 d_4| & |a_1 b_2 c_3 d_5| & |a_1 b_2 c_3 d_6| \\ |a_1 b_2 c_3 e_4| & |a_1 b_2 c_3 e_5| & |a_1 b_2 c_3 e_6| \\ |a_1 b_2 d_3 f_4| & |a_1 b_2 d_3 f_5| & |a_1 b_2 d_3 f_6| \end{vmatrix} = \dots = |a_1 b_2 c_3| \cdot |a_1 b_2 d_3| \cdot \Delta_6,$$

the number of instances of the type being

$$C_{6,2} \times C_{4,2} \times 2, \text{ i. e. } 180.$$

(7) If *five* letters are to be used, only one of them, *f* say, must occur twice; its companions must be two, *d* and *e* say, of the remaining five; and the third row must have two, *b* and *c* say, of the remaining three. The factorisation of such an auxiliary is

$$\begin{vmatrix} e_5 f_6 & e_4 f_6 & e_4 f_5 \\ d_5 f_6 & d_4 f_6 & d_4 f_5 \\ b_5 c_6 & b_4 c_6 & b_4 c_5 \end{vmatrix} = |d_4 e_5 f_6| \cdot |b_4 c_5 f_6|,$$

from which we obtain

$$\begin{vmatrix} a_1 b_2 c_3 d_4 & a_1 b_2 c_3 d_5 & a_1 b_2 c_3 d_6 \\ a_1 b_2 c_3 e_4 & a_1 b_2 c_3 e_5 & a_1 b_2 c_3 e_6 \\ a_1 d_2 e_3 f_4 & a_1 d_2 e_3 f_5 & a_1 d_2 e_3 f_6 \end{vmatrix} = |a_1 b_2 c_3| \cdot |a_1 d_2 e_3| \cdot \Delta_6,$$

the full number of the type being

$$C_{6,1} \times C_{3,2} \times C_{3,2} \text{ i. e. } 180.$$

(8) When *all* the letters are used the type of auxiliary equality is

$$\begin{vmatrix} e_5 f_6 & e_4 f_6 & e_4 f_5 \\ e_5 d_6 & e_4 d_6 & e_4 d_5 \\ a_5 b_6 & a_4 b_6 & a_4 b_5 \end{vmatrix} = \begin{vmatrix} e_4 e_5 f_6 & d_4 e_5 f_6 \\ a_4 b_5 c_6 & a_4 b_5 d_6 \end{vmatrix},$$

whence we have

$$\begin{vmatrix} a_1 b_2 c_3 d_4 & a_1 b_2 c_3 d_5 & a_1 b_2 c_3 d_6 \\ a_1 b_2 e_3 f_4 & a_1 b_2 e_3 f_5 & a_1 b_2 e_3 f_6 \\ c_1 d_2 e_3 f_4 & c_1 d_2 e_3 f_5 & c_1 d_2 e_3 f_6 \end{vmatrix} = \begin{vmatrix} a_1 b_2 d_3 & a_1 b_2 c_3 \\ d_1 e_2 f_3 & c_1 e_2 f_3 \end{vmatrix} \cdot \Delta_6,$$

the resolvability in this case being only partial. The number of instances is readily seen to be 15.

(9) Summarising the results of this census of the resolvability of 455 3-line minors of the 4th compound of $|a_1 b_2 c_3 d_4 e_5 f_6|$ we have—

$$20 \text{ of the type } |a_1 b_2 c_3|^2 \cdot \Delta_6,$$

$$60 \text{ " " " } 0,$$

$$180 \text{ " " " } |a_1 b_2 c_3| \cdot |a_1 b_2 d_3| \cdot \Delta_6,$$

$$180 \text{ " " " } |a_1 b_2 c_3| \cdot |a_1 d_2 e_3| \cdot \Delta_6,$$

$$15 \text{ " " " } \begin{vmatrix} |a_1 b_2 d_3| & |a_1 b_2 c_3| \\ |d_1 e_2 f_3| & |c_1 e_2 f_3| \end{vmatrix} \cdot \Delta_6.$$

In regard to the second of the six groups it must be carefully noted that the 0 (zero) given as the result is not $0 \cdot \Delta_6$, the truth being that the process of elimination by instalments here fails, and of course properly so, because the 0 arises from the fact of it being possible to choose from our set of 15 equations in *x, y, z* three equations that are not mutually independent—a possibility that in our original statement in § 2 was only hinted at. Further, it is worth noting that these determinants of zero value bear an external mark that fully warns us against accepting them as multiples of

the true eliminant like the others, namely, the entire absence of one of the six necessary letters.

(10) In the 4th compound of Δ_6 there are nineteen other arrays which are quite similar in extent and character to that dealt with in the foregoing, and which thus have the factorisation of their 3-line determinants equally fully known.

RONDEBOSCH, S.A.;

24th September, 1919.

SOUTH AFRICAN MICROTHYRIACEAE.

BY ETHEL M. DOIDGE.

(With Plates XIII-XIX.)

The family *Microthyriaceae* was first described by Saccardo ('Syll. Fung.' ii, p. 658, 1883) as follows: "Simplices (*i.e.*, without a stroma) Perithecia subsuperficiala, nigricantia, membranacea vel carbonacea, dimidiata, applanata, contextu plerumque eximio radiato, centro pertusa vel astoma. Asci 4-8 spori, saepe breves." In describing fungi in those early days, the morphological structure of the reproductive bodies was not minutely studied, and gradually a large number of genera and species of very varying character was assigned to the *Microthyriaceae*. The only character which these forms theoretically had in common was the flattened, shield-like form of the perithecia. In practice even this characteristic was not always taken into account. During the last ten years, however, the enormous task of revision has been carried out chiefly by von Höhnelt (1) and Theissen (2-10); a large number of genera, including all forms which are not strictly superficial, have been excluded, and the whole group completely reorganised.

In Engler's 'Die Pflanzenfamilien,' 1897, Lindau includes the *Microthyriaceae* in the group *Perisporiales* with the *Erysiphaceae* and the *Perisporiaceae*; but although they have some points in common, the *Microthyriaceae* differ widely from the other two families in the form of the fruiting body, which is not a "perithecium" in the true sense of the word, but a flattened, shield-shaped structure, usually in the form of a flattened hemisphere. Theissen classifies together all the superficial ascomycetes with hemispherical fruiting bodies (which he terms "thyriothechia") in a new group, the *Hemisphaeriales* (6, 8). Within this group he distinguishes three families: the *Microthyriaceae*, with filamentous mycelium and thyriotheccial membrane formed of radiating hyphae; the *Hemisphaeriaceae*, which differ from the *Microthyriaceae* in the more or less reticulate—not radiate—structure of the thyriotheccial membrane; and the *Trichopeltaceae* (9), which, instead of a network of filamentous hyphae, form a ribbon-like thallus in which the thyriothechia are developed pycnotically.

Of these three families this paper only deals with the *Microthyriaceae* as delimited by Theissen. He assigns to this family some twenty genera, of which only eight have representatives described as occurring in South Africa.

General Characteristics.

The mycelium may be persistent or evanescent; in the latter case it is poorly developed, and disappears as soon as the thyriothecia are formed.

The genus *Asterina* (2) may be taken as typical of the family; in this genus the spore germinates at one or both poles, as a general rule sending out first a small papilla of limited growth which closely resembles in form the hyphopodia on the mycelium; one or two germ tubes are subsequently developed from each pole, and these elongate, forming septate hyphae which branch alternately and produce hyphopodia at more or less regular intervals. The hyphopodia are extremely varied in form, and are of the greatest diagnostic value. Alternate branching is the rule, but in some species opposite branching is predominant. The mycelium develops centrifugally, and the mother spore can long be detected unaltered in the centre; its persistent character is often useful in determining the nature of the epispore at maturity, when the spores in the ascus are more or less immature. In a few species of *Asterina* typical hyphopodia are not developed, their place being taken by so-called "node-cells," which are spherical or hemispherical, swollen cells placed at regular intervals. These species may be regarded as intermediate forms between the genus *Asterina* and genera like *Asterinella* (3), in which no hyphopodia are developed.

The thyriothecium originates from a medial cell of a hypha, or from the terminal cell of a short lateral branch. In either case the initial cell divides rapidly and forms a group of small polyhedral cells between the hypha and the leaf surface. Each of the cells comprising this group begins to grow in a radial direction, each one forming a radiating hypha which is in close contact with its neighbour and is attached to it by the radial walls. The increase in circumference, as the disk increases in size, is provided for by the repeated bifurcation of the constituent hyphae. These are sometimes connected throughout their length, forming a compact disk with an entire or crenate margin; but more frequently they are free at the circumference, giving the thyriothecium a fimbriate appearance. The central part has meanwhile become arched to form the perithecial cavity, while the peripheral zone remains appressed to the leaf surface. Theissen regards this structure as a development of the complete spherical form found in the *Perisporiaceae*; the thyriothecium consists only of the basal half, which has been turned upside down, and hence is called "inverse." This inverse form, together with the radial-prosenchymatous structure of the membrane, is typical of the thyriothecia of the *Microthyriaceae* proper.

The thyriothecium has no typical ostiole; at maturity the initial group of cells may break away, forming a central pore, but the spores usually escape—in the genus *Asterina*—through radial or irregular fissures in the membrane. In *Lembosia* and its allied genera the thyriothecium dehisces by a longitudinal slit, and in the genus *Englerulaster* the outer membrane

breaks down from the centre, falling apart into separate cells, with abundant secretion of mucilaginous matter.

The pycnidia (*Asterostomella*) in the genus *Asterina* are usually identical in form with the thyriothecia, but they are smaller; these were often mistaken by the earlier workers for thyriothecia, and described as such, the brown, continuous conidia being taken for ascospores and described as a separate genus *Asteronia*. Of the conidia of *Asterinella* Theissen (3) says very little, but mentions conidia of the *Asterostomella* type in one species, and in his key to the genera he includes the genus in the section with one-celled conidia. Of the four South African species one has conidia of the *Asterostomella* type, one has hyaline, curved, aseptate conidia, and in a third they are hyaline, fusiform and four-celled; in each case they are borne in pycnidia resembling thyriothecia.

In the genus *Clypeolella* the conidia are four-celled, and are borne on the mycelial hyphae; more than one superficial fungus has been collected showing this type of conidium, but in every case the thyriothecia were very immature, so that it was impossible definitely to identify any one of them as a *Clypeolella*, and it is still uncertain whether this genus occurs in South Africa.

The asci may be paraphysate or aparaphysate, and in some cases the presence or absence of paraphyses is used as a generic distinction; they vary in form from elliptic or clavate to spherical. There is also considerable variety in the spore forms of the different genera, but in the majority they are two-celled, and either hyaline or brown.

THE SOUTH AFRICAN GENERA.

The genus *Asterina* Lév. has the largest number of species. In his monograph on this genus, Theissen describes 108 species, of which 55 are from South America; he only records 6 genuine species from Africa. A much larger number of fungi has been described from South Africa as belonging to the genus *Asterina*, the greater part collected by MacOwan and Medley Wood, and described by Kalchbrenner and Cooke in Grevillea; a few were described at a later date by Winter, Hennings, and Sydow, making 22 species in all. Of these 11 are excluded as not belonging to the *Microthyriaceae* as now defined; Theissen excludes a still greater number on account of the absence of thyriothecia in the type specimens, but a number of these I have fortunately been able to re-collect and re-describe.

In the present paper 30 species of *Asterina* are recorded from South Africa, and are represented in the National Herbarium, Pretoria. These are as follows:

Sub-genus *Dimerosporium*.—13 new species; 1 new variety of a Brazilian species; 4 amplified descriptions of species previously recorded but imper-

fectly described, or type not showing thyriothecia; 4 species previously described.

Sub-genus *Clypeolaster*.—1 new species; 2 new varieties; 3 species previously described, and 2 species recorded from Brazil.

The limits of the genus *Asterina* are not at all sharply defined; the typical form of the thyriothecium is the flattened hemisphere, but not infrequently elongated thyriothecia occur amongst the hemispherical ones; the round *Asterina* thyriothecia graduate into the linear *Lembosia* form, and in some species it is difficult to decide which is the predominating type. The chief distinction between these genera, apart from the shape of the thyriothecium, is that in *Lembosia* the asci are elliptical or cylindrical, and paraphysate, while in *Asterina* they are more or less spherical, and in the sub-genera *Dimerosporium* and *Clypeolaster* they are a paraphysate; but this character does not serve to distinguish the genus *Lembosia* from the genus *Parasterina*, which also has paraphysate asci.

On the other hand, the thyriothecia often approach the sub-spherical form of *Englerulaster*; in the latter genus the cells of the thyriothecial membrane fall apart from the centre outwards, with abundant formation of mucilaginous matter; in some species of *Asterina* the central cells break down in a very similar way, but the process does not extend outwards to the circumference; the dividing line between the genera *Asterina* and *Englerulaster* is, therefore, not at all sharp.

The same applies to the genera *Asterina* and *Asterinella*; the *Asterina* species with regular node-cells approach very close to the *Asterinella* species with more or less torulose mycelium. The genus *Seynesia*, which is an *Asterina* without persistent mycelium, is only represented by one species, and so also the genera *Microthyrium*, *Amazonia* and *Morenoina*. In the genus *Lembosia* three species are described, of which only one has been previously recorded; none of the four species of *Asterinella* described agree with any of the species mentioned in Theissen's monograph of the genus. *Morenoella*, which differs from *Lembosia* only in the absence of paraphyses, is represented by one species hitherto undescribed. *Englerulaster Gymnosporiae* was included in a previous paper (11) in the genus *Dimerium*; of the other two species now described, one has only been recorded from North America, and the other is apparently new to science.

GEOGRAPHICAL DISTRIBUTION, ETC.

It has been pointed out in connection with the genus *Asterina* that a large proportion of the described species are South American, and this is equally true of the other genera of the *Microthyriaceae*, but whether this indicates that there are actually a larger number of species in South America, or that more complete collections have been made there than in Africa, remains to be proved.

The distribution of the family in South Africa coincides with that of the *Perisporiaceae*, abundant material being found in all the humid, wooded districts; but the collection in the National Herbarium is necessarily still very incomplete, and no collections at all have been made in many very promising localities.

A series of permanent microscopic preparations has been made by the collodion method (11) of all the specimens mentioned, and is kept for reference in the Union Botanical Laboratory, Pretoria. For the determination of the greater part of the host plants, particularly those collected in the Transvaal, I am indebted to Miss S. M. Stent, to Dr. J. W. Bews and Mr. T. R. Sim for the identification of a number of Natal plants, and to Dr. S. Schönland and Miss Gane of the Albany Museum, for naming a large collection of plants from the Eastern Province. I am also indebted to Miss A. Pegler and others for a number of very interesting specimens.

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MICROTHYRIACEAE.

Mycelium persistent or evanescent, thyriothecia superficial, inverse, radiate, flattened-hemispherical or linear; asci paraphysate or aparaphysate, 2-8-spored, elliptic or clavate to sub-spherical. Spores varying in form,

hyaline or brown. Occur on living leaves and young parts of plants in humid situations.

Key to the Genera.

(After Theissen, Myk. Centralb. iii, p. 281.)

- A. Free mycelium wanting.
 - I. Spores 1-celled.
 - a. Spores hyaline *Myocopron*.
 - b. Spores brown ? *Vizella*.
 - II. Spores 2-celled.
 - a. Spores hyaline *Microthyrium*.
 - b. Spores brown.
 - x. Thyriotheceum circular *Seynesia*.
 - xx. Thyriotheceum linear.
 - i. Asci paraphysate *Lembosina*.
 - ii. Asci aparaphysate *Morenoina*.
 - III. Spores 3-celled, brown, walls sub-polar *Scutellum*.
 - IV. Spores 4-celled, brown *Halbania*.
 - V. Spores more than 4-celled, hyaline *Phragmothyrium*.
 - VI. Spores linear, filiform ? *Ophiopeltis*.
- B. Free mycelium present.
 - I. Spores 1-celled, brown *Lembosiella*.
 - II. Spores 2-celled.
 - x. Spores hyaline.
 - 1. Thyriotheceia round.
 - i. Mycelium with hyphopodia ? *Asterella*.
 - ii. Mycelium without hyphopodia *Calothyrium*.
 - 2. Thyriotheceia linear *Lembosiopsis*.
 - xx. Spores brown.
 - 1. Thyriotheceia round.
 - i. Mycelium with hyphopodia.
 - o. Thyriotheceial wall 1-layered, conidia 4-celled *Clypeolella*.
 - oo. Thyriotheceial wall with more than one layer of cells, conidia usually 1-celled.
 - / . Thyriotheceial membrane secreting mucilage externally and internally, breaking down centrifugally and becoming separated into single cells *Englerulaster*.

- //. Thyriothecial membrane
not secreting mucilage
externally, at the utmost
breaking down only in
the centre.
 - a. Asci paraphysate . *Parasterina*.
 - b. Asci aparaphysate . *Asterina*.
- ii. Mycelium without hyphopodia . *Asterinella*.
- 2. Thyriothecia linear.
 - i. Asci paraphysate.
 - a. Mycelium hyphopodiate . *Lembosia*.
 - b. Mycelium non-hyphopodiate . *Echidnodes*.
 - ii. Asci aparaphysate.
 - a. Mycelium hyphopodiate . *Morenoella*.
 - b. Mycelium non-hyphopodiate . *Echidnodella*.
- III. Spores 5-celled, brown *Amazonia*.

MICROTHYRIUM Desm.

Ann. Sc. nat. xv, p. 137 (1841) ; Syll. Fung. ii, p. 662.

Thyriothecia superficial, dimidiate, flattened-hemispherical, formed of radiating hyphae. Asci aparaphysate. Spores hyaline, 2-celled. Free mycelium absent.

Microthyrium maculicolum Doidge, sp. nov.

Plate XVIII, fig. 40. Slide XLVI, 18.

Epiphyllous, forming raised, blister-like, light-brown areas up to 1 cm. diam. on the upper side of the leaf, on which the thyriothecia are visible as minute black points. Mycelium pale, effuse, evanescent. Thyriothecia dark brown, numerous, scattered or sub-gregarious, flattened hemispherical, sometimes more or less angular by contact, 150–190 μ diam.; composed of radiating hyphae 3–4 μ thick, cells 3–10 μ long, central cells almost cubical, the more elongated ones near the circumference, margin entire. Asci 8-spored, not numerous, usually 3–7 in each thyriothecium, aparaphysate, elliptical with broadly-rounded apex, 70 \times 27 μ , or obovate, 50–57 \times 30–43 μ , apedicellate, uniformly thinly tunicated, wall barely 1 μ thick. Spores conglobate or sub-parallel, hyaline, 1-septate, upper loculus decidedly broader, 21–23.5 \times 6.5–10 μ .

On leaves of *Capparis*? sp., Durban, 11/4/18, Bottomley, 11668.

SEYNESIA Sacc.

Syll. Fung. ii, p. 668.

Similar to *Microthyrium*, but spores brown.

Seynesia orbiculata Syd.

Ann. Myc. x (1912), p. 39.

Thyriothecia epiphyllous, gregarious, always forming orbicular groups 4–8 mm. diam., very closely packed, opaque, formed of radiating hyphæ, mostly hemispherical, 90–175 μ diam., less frequently somewhat elongated or irregular, in which case they are longer. No free mycelium. Asci ovate to clavate, thickened at the apex, 35–60 \times 16–25 μ , 8-spored. Spores distichous or conglobate, ellipsoid, rounded at both ends, 1-septate, constricted, smooth, brown, 13–18 \times 6–8 μ , cells equal.

On leaves of *Euclea* sp., Letaba Drift, Zoutpansberg Dist., 6/8/11, Doidge, 1808.

MORENOINA Th.

Ann. Myc. xi (1913), p. 434.

Free mycelium wanting; thyriothecia linear to oblong, inverse, radial-prosenchymatous in structure, asci aparaphysate, spores 2-celled, brown.

Morenoina africana Doidge sp. nov.

Plate XVIII, fig. 41. Slides XLIV, 15, 16.

Epiphyllous; mycelium none, or represented by a few pale, poorly developed hyphæ. Thyriothecia scattered or confluent in small groups, linear-ellipsoid, 120–400 \times 65–100 μ , straight or slightly curved, less frequently somewhat sinuous or forked, dehiscing by a longitudinal slit almost the length of thyriothecium; radiating hyphæ 2.5–3 μ thick, cells almost cubical; margin fimbriate. Asci (immature) aparaphysate, ellipsoid-clavate, briefly pedicellate, 23–27 \times 10–12 μ , not staining blue with iodine. Mature spores only seen outside the ascus, fuscous, 2-celled, scarcely constricted, smooth, 12–14 \times 5–6.5 μ , cells equal.

On pinnules of *Dryopteris inaequalis*, Zwartkop, Natal, 19/7/18, Doidge, 11605.

ENGLERULASTER von Höhn.

Fragm. z. Myk., Bd. x, Nr. 520.

Mycelium superficial, branched, septate, with regular hyphopodia. Thyriothecia hemispherical or almost spherical, inverse, radial-prosenchymatous; at maturity the thyriothecial membrane breaks down from the centre, falling apart into separate cells, with abundant formation of mucilaginous matter. Ascospores brown, 2-celled.

Key to the Species.

- | | |
|---|-----------------------------|
| a. Spores not more than 30 μ long. | |
| a. Thyriothecia 90–110 μ diam. | 1. <i>E. Gymnosporiae</i> . |
| b. Thyriothecia 160–190 μ diam. | 2. <i>E. Popowiae</i> . |
| b. Spores 33–36 μ long | 3. <i>E. orbicularis</i> . |

1. *Englerulaster Gymnosporiae* (P. Henn.), Th.

Slide I, 16.

Beih. Bot. Centralb. 1912, pp. 51-54; Myk. Centralb. iii, p. 277.

Dimerium Gymnosporiae (P. Henn.), Syd. Ann. Myc. vii (1909), p. 546; Trans. Roy. Soc. of S. Af. v, Part vi, p. 719, Pl. lviii, f. 7.*Dimerosporium Gymnosporiae* P. Henn. Syll. Fung. xvi, p. 408.

Epiphyllous or amphigenous, sub-crustaceous; mycelium pale fuscous, radiating, effuse, hyphae 7-11 μ thick, sinuous, septate, with a few small hyphopodia; hyphopodia sessile, 1-celled, hemispherical. Thyriothecia gregarious, hemispherical, black, opaque, 90-110 μ diam. Asci ovoid, rounded at the apex, sub-tunicated, attenuated at the base, sometimes very briefly pedicellate, 35-50 \times 30-45 μ , 8-spored, paraphysate. Spores conglobate, ovoid, 1-septate, constricted, fuscous, 18-24 \times 10-13 μ .

On leaves of *Gymnosporia* sp., Umbelusi, Portuguese East Africa, Howard, 523; Empangeni, Natal, 11/7/17, v. d. Bijl, 11367.

On *Putterlickia*, sp. Isipingo, Natal, 21/5/15, Doidge, 10154.

2. *Englerulaster Popowiae* Doidge, sp. nov.

Plate XIII, fig. 1. Slide XLV, 6.

Epiphyllous, forming thin black spots up to 5 mm. diam.; mycelium brown, radiating; hyphae 5-6 μ thick, frequently septate; branching opposite or irregular; hyphopodia sessile, alternate or unilateral, occasionally opposite, capitate to ellipsoid, some at right angles to the hyphae, others bent or curved inwards, broadening at the base, 10-13.5 \times 6-8 μ , sometimes up to 16 μ in length. Thyriothecia dark brown but seldom quite opaque, 160-190 μ diam., radiating hyphae 5-6 μ thick, margin coarsely fimbriate, dehiscence by an irregular central fissure which extends outwards to the margin and leaves the ripening asci exposed. Asci spherical to ovate, 8-spored, apedicellate, not tunicated, often slightly angular by compression, 40-47 \times 30-40 μ , paraphysate. Spores brown, 2-celled, constricted, cells equal or upper loculus slightly larger, each loculus almost spherical, minutely scabrous when mature, 21-27 \times 10-13.5 μ .

On leaves of *Popowia caffra*, Buccleuch, Natal, 24/3/16, Doidge, 9714; East London, 24/11/17, Doidge, 10917.

3. *Englerulaster orbicularis* (B. & C.) v. Höhn.

Fragmente z. Myk. 520, Sitz. Ber. k. Akad. d. Wiss. math.-nat. Klasse.

Asterina orbicularis B. & C., Grevillea, iv, p. 8; Syll. Fung. i, p. 46; onliving leaves of *Ilex coriacea*, Florida, Rabh.-Wint. Fung. Eur. 3439.*Dimerosporium orbiculare* Mart., Journ. of Myc. i, p. 146; Ell. & Ev.

North American Pyrenomycetes, p. 32.

Plate XIII, fig. 2. Slides XVI, 1, 2; XXIII, 13-16; XXIV, 1, 10;

XLII, 11-13.

Amphigenous, forming black, crustaceous spots, 3-5 mm. diam.; when numerous they become confluent and produce irregular, black blotches covering large areas of the leaf surface. Mycelium radiating, branching and anastomosing freely; hyphae brown, straight, 5-6 μ thick, branching opposite or alternate; cells 10-15 μ long; hyphopodia alternate or opposite, sessile, hemispherical, flattened or shortly cylindrical, 5-8 \times 5-6 μ . Thyriothecia scattered, hemispherical, opaque, 150-170 μ diam., radiating cells 3-3.5 μ thick, cells cubical, margin not fimbriate, but the thyriothecia are surrounded by a dense network of hyphae. Asci paraphysate, 8-spored, broadly ovate or sub-spherical, 54-57 \times 44-50 μ , much thickened round the apex. Spores conglobate, 2-celled, brown, slightly constricted, 33-36 \times 15-18 μ , cells equal or subequal, epispore minutely verrucose at maturity. Pycnidia similar to the thyriothecia but smaller, 60-120 μ diam.; conidia brown with a hyaline band, oval or ovate, 15-25 \times 8-14 μ .

On leaves of *Ilex capensis*, Woodbush, Zoutpansberg, 4/8/11, Doidge, 1753; Brander's High Forest, Victoria East, 14/8/15, v. d. Bijl, 9461; Zwartkop, Natal, 15/8/17, T. R. Sim, 10574; Van Staden's Pass, 13/11/17, Doidge, 10884; Woodville Forest, George, 11/11/17, Doidge, 10943; Buccleuch, Natal, 17/7/18, Doidge, 11563.

PARASTERINA Theiss. et Syd.

Ann. Myc. xvii (1915), p. 246.

Like *Asterina*, but asci paraphysate.

Hyphopodia sessile.

- | | |
|---|----------------------------|
| a. Spores 35-40 μ long | 1. <i>P. implicata</i> . |
| b. Spores not more than 35 μ long. | |
| x. Hyphopodia never opposite | 2. <i>P. Brachystoma</i> . |
| xx. Hyphopodia usually opposite | 3. <i>P. rigida</i> . |

1. *Parasterina implicata* Doidge, sp. nov.

Plate XIII, fig. 3. Slide XXXIII, 2.

Epiphyllous, forming round-irregular, black, crustaceous spots 3-5 μ diam. Hyphae brown, 6-7 μ thick, torulose, branching irregularly and anastomosing freely to form a network of entangled hyphae, tips of branches often club-shaped; cells 14-25 μ long; hyphopodia sessile, not very numerous, alternate or unilateral, hemispherical, ovate or obliquely flattened, 6-10 \times 10-6 μ . Thyriothecia gregarious, flattened-hemispherical, 300-400 μ diam., composed of radiating hyphae 3.5-5 μ thick, dehiscence irregular or stellate. Asci ovate to spherical, 8-spored, paraphysate, slightly thickened round the apex, 57-73 \times 50-57 μ ; paraphyses numerous, filiform. Spores conglobate, 2-celled, fuscous, smooth, constricted, 35-40 \times 13-15 μ , upper cell broader.

On leaves of *Sideroxylon inerme*, East London, 24/11/17, Doidge, 10922.

2. *Parasterina brachystoma* (Rehm.) Th.

Die Gattung *Asterina*, p. 49.

Seynesia brachystoma Rehm., Hedwigia, 1898, p. 325; Syll. Fung. xvi, p. 641, on leaves of a tree, Serra do mar, Central Brazil; Ule 569 Herb. Pazschke and Berlin, on Myrtaceae leaves, Ule 1238; Herb. Berlin sub *Seynesia colliculosa* Rehm.

Asterina multiplex Rehm., Ascom. 1706. On living leaves of *Styrax leprosum*, São Leopoldo, Rio Grande do Sul, South Brazil; Theissen, Decades F. Bras. 59.

Asterina megalosperma Speg. in herb; on leaves of *Styrax*?, Ipiranga no. 16.

Also Ule 1143, Herbar. Pazschke, on an Anonaceae sub *Asterina paraguayensis*.

Plate XIII, fig. 4. Slides XXVI, 16; III, 7-9; XXXV, 11.

Epiphyllous, forming black, carbonaceous spots, round to irregular, up to 10 mm. diam. Mycelium radiating, branching alternately and anastomosing to form a network; hyphae straight, brown, 6-8 μ thick, frequently septate, cells 10-16 μ long, walls often oblique; hyphopodia alternate, sessile, continuous, very briefly cylindrical or subglobose, 7-11 \times 6-10 μ . Thyriothecia hemispherical, gregarious, 280-400 μ diam., consisting of straight, brown hyphae about 3 μ thick, cells almost cubical; dehiscence stellate; margin dentato-crenulate, certain stout hyphae running out into the mycelium. Asci paraphysate, broadly ovate, sessile, thickened at the apex, about 55 \times 45 μ , 8-spored; paraphyses filiform, swollen at the tips, which become conglutinate. Spores conglobate, brown, smooth, oblong, 2-celled, slightly constricted, rounded at both ends, 30-35 \times 14-17 μ (Thiessen makes the spores 33-37 μ long), cells equal in length, but the upper loculus somewhat broader.

On leaves of *Eugenia Zeyheri*, Woodbush, Zoutpansberg, 3/8/11, Doidge, 1759; March, 1910, Gray, 888.

On *Eugenia Gerrardi*, Buccleuch, Natal, 23/3/16, Doidge, 9723; 20/4/16, J. M. Sim, 10141.

On shrub undetermined (*Myrtaceae*?), Zwartkop, Natal, 19/7/18, Doidge, 11597.

var. *Laxa* Doidge, var. nov.

Slides XXVI, 17, 18; XXXIX, 7.

Mycelium more slender and more opaque than in the type; hyphopodia more distant and slightly smaller.

On leaves of *Grumilea capensis*, Woodbush, Zoutpansberg, 3/8/11, Doidge, 1758.

On *Oxyanthus Gerrardi*, Berea, Durban, 28/1/17, v. d. Bijl, 11017.

On *Oxyanthus natalensis*, Berea, Durban, 28/1/18, v. d. Bijl, 11366.

3. *Parasterina rigida* Doidge, sp. nov.

Slide XXXVIII, 12. Plate XIII, fig. 5.

Epiphyllous, forming black, carbonaceous spots up to 7 mm. diam., mostly on the primary veins. Hyphae brown, 5–6 μ thick, branches mostly alternate, anastomosing; cells 16–20 μ long; hyphopodia numerous, usually opposite, sessile, hemispherical to ovate, 6–8 \times 5–6 μ . Thyriothecia gregarious, flattened-hemispherical, 250–400 μ diam., formed of radiating hyphae about 5 μ thick, dehiscing by an irregular disruption of the central cells. Asci paraphysate, broadly elliptic to ovate, 60–75 \times 30–40 μ , thickened round the apex, which is traversed by a pore; paraphyses filiform, somewhat swollen at the tips and not so long as the asci. Spores conglobate, fuscous, 2-celled, constricted, 27–33 \times 13–15 μ , upper loculus larger than the lower. On leaves of *Oncinotia inandensis*, Buceleuch, Natal, 11/5/16, Doidge, 9722.

ASTERINA Lév.

Ann. d. Sc. natur., Sér. iii (Bot.), Bd. iii, 1845, p. 59.

Mycelium superficial, branched, septate, with regular hyphopodia or node-cells. Thyriothecia flat to hemispherical, inverse, radial-prosenchymatous in structure, without a regular ostiole; spores escape through fissures in the thyriothecial membrane. Asci aparaphysate. Ascospores brown, 2-celled. Pycnidia similar to the thyriothecia, pycnoconidia brown, 1-celled (*Asterostomella*); mycelial conidia 1-celled or wanting.

Key to the Sections.

- A. Thyriothecia without basal membrane. Sub-genus I—DIMEROSPORIUM.
 B. Thyriothecia with basal membrane. Sub-genus II—CLYPEOLASTER.

Sub-genus I. DIMEROSPORIUM Fekl.

1869. Sym. Myc., p. 89; (*Myzasterina*) v. Höhn. Fragm. z. Myk., no. 331 (vii, p. 58), 1909.

Thyriothecia without basal membrane, asci aparaphysate.

- A. *Nodulosae*: hyphae without true hyphopodia, but with swollen node-cells.
 a. Nodes 7–10 μ diam. 3. *A. gibbosa* var. *megathyria*.
 B. *Hyphopodiatae*: hyphae with true hyphopodia.
 a. Hyphopodia 2-celled.
 1. Spores verrucose or ciliate.
 i. Spores 15–19 μ long, thyriothecia 120–130 μ diam. 4. *A. natalensis*.
 ii. Spores 18–23 μ long, thyriothecia 140–180 μ diam. 5. *A. Combreti*.
 iii. Spores 23–28 μ long 6. *A. Peglerae*.

2. Spores smooth.
 - i. Spores 15-18 μ long 5. *A. tenuis*.
 - ii. Spores 18-24 μ long.
 - x. Thyriothecia 130-150 μ diam. 6. *A. fimbriata*.
 - xx. Thyriothecia 160-240 μ diam. 7. *A. reticulata*.
 - iii. Spores 30-34 μ long 8. *A. uncinata*.
- b. Hyphopodia 1-celled.
 1. Hyphopodia entire or with slight indentations, not deeply lobed.
 - i. Hyphopodia angular or sub-lobed 9. *A. delicata*.
 - ii. Hyphopodia finger- or flask-shaped.
 - x. Spores smooth 10. *A. Grewiae*.
 - xx. Spores minutely verrucose 11. *A. Trichiliae*.
 - iii. Hyphopodia hemispherical or shortly and broadly cylindrical.
 - x. Spores 15-18 μ long 12. *A. raripoda*.
 - xx. Spores 23-26 μ long.
 - o. Thyriothecia dehiscing by a stellate fissure 13. *A. ferruginosa*.
 - oo. Thyriothecia dehiscing by an irregular spherical rupture.
 - / . Thyriothecia 225-280 μ diam., radiating hyphae straight 14. *A. rhamnicola*.
 - // . Thyriothecia 150-200 μ diam., radiating hyphae tortuous 15. *A. Hendersoni*.
 - xxx. Spores 26-28 μ long 16. *A. opaca*.
 - zzxx. Spores 35-40 μ long 17. *A. robusta*.
 2. Hyphopodia lobed.
 - i. Spores verrucose.
 - x. Spores 20-23 \times 10-12 μ 18. *A. erysiphoides*.
 - xx. Spores 17-22 \times 8-10 μ 19. *A. Balansae* var. *africana*.
 - xxx. Spores 23-27 \times 12-13.5 μ 20. *A. Ezcoecariae*.
 - ii. Spores smooth.
 - x. Spores 13-15 μ long 21. *A. undulata*.
 - xx. Spores 16-20 μ long 22. *A. polythyria*.

3. *Asterina gibbosa* Gaill.

Bull. Soc. Myc. 1897, p. 180; Syll. Fung. xiv, p. 697; Die Gattung *Asterina*, p. 57, T. lv, fig. 7, v, 3-4, vii, 29-30, viii, 3, Rabh. W.P.F. eur. 4054, Tuberao, Sta. Catharina, South Brasil; Balansa, Plantes

du Paraguay 3839 (Herb. Kew) on *Randia* sp., Guarapi, Brasil; on *Basanacantha spinosa*, São Leopoldo, Rio Grande do Sul, Herb. Theissen.

var. *megathyria* Doidge, var. nov.

Plate XIII, fig. 6. Slides XI, 16-19; XIII, 10; XXXI, 15; XXXII, 16, 17; XXXIV, 4; XLI, 7.

Mostly epiphyllous, forming minute, orbicular, black, crustaceous spots, 1-3 mm. diam; when the spots are hypophyllous they frequently become confluent. Mycelium not effuse, irregularly branched; hyphae flexuous, 4-6 μ thick, radiating, olivaceous-brown; cells 10-20 μ long; nodes 7-10 μ thick, asymmetrical, more or less spherical. Thyriothecia very numerous, densely aggregated and becoming confluent, flattened-hemispherical, outline orbicular or flattened by contact, 140-200 μ diam., composed of straight, radiating hyphae 2-4 μ thick, cells 4-6 μ long; margin not fimbriate, dehiscence stellate. Asci paraphysate, ovate to sub-clavate, 8-spored, thickly tunicated, especially round the apex, 33-34 \times 27-33 μ . Spores ellipsoid, 1-septate, slightly constricted, light olivaceous brown, smooth, 16-20 \times 8-9 μ ; upper locus sub-spherical, 8-9 μ diam.; lower locus ellipsoid, 9-12 \times 8 μ .

On *Tricalysia Sonderiana*, nr. Durban, 25/5/1897, Wood (Wood No. 6452 sub. *A. tenuis*).

On *Tricalysia lanceolata*, Amanzimtoti, 10/7/11, Doidge, 1576; Winters Kloof, 27/6/11, 1/6/15, Doidge, 1624, 8987; Claridge, 31/5/15, Doidge, 8992; Kentani, 16/12/14, Pegler (Pegler, 1970), 8787.

On *Randia dumetorum*, Amanzimtoti, 10/7/11, Doidge, 1682; Lemana, Zoutpansberg, 14/8/11, Doidge, 1792; Umgeni, Durban, 10/7/15, Wood, 9031.

On *Pavetta obovata*, Krantzkloof, Natal, 26/5/15, Doidge, 8985.

On *Alberta*? sp., Buccleuch, Natal, Doidge, 10151.

On *Plectronia Guenzii*, Hogg's Back, 15/1/18, J. & M. Henderson, 11347.

Differs from the type in the size of the asci and thyriothecia; the latter are much larger and the radiating hyphae composing the thyriothecial membrane narrower than in the type. The specimens from South Brazil have very small thyriothecia, 50-90 μ diam., with radiating hyphae 4-5.5 μ thick.

This species occurs very commonly on *Rubiaceae*, and has been collected a number of times, especially in Natal.

2. *Asterina natalensis* Doidge, sp. nov.

Plate XIII, fig. 7. Slide XXXI, 11.

Epiphyllous, forming thin black spots 2-4 mm. diam.; mycelium slender, branching irregularly and anastomosing; hyphae 3-5 μ thick, hyphopodia fairly numerous, alternate or occasionally opposite, stipitate, 2-celled, upper

cell slightly lobed or hooked, $8-14 \times 6-10 \mu$. Thyriothecia $120-130 \mu$ diam., flattened-hemispherical; margin fimbriate; dehiscence stellate; composed of radiating hyphae $3-3.5 \mu$ thick, cells almost cubical, about 4μ long. Asci paraphysate, broadly cylindrical or spherical, somewhat thickened round the apex, $26-32 \times 20-24 \mu$. Spores conglobate, 2-celled, constricted, $15-19 \times 9-10 \mu$, brown, upper loculus slightly broader; epispore very minutely scabrous at maturity. Pycnidia similar to the thyriothecia but slightly smaller; conidia ovate, brown with a lighter medial band, $13-17 \times 8-10 \mu$.

On leaves of *Mikania* sp., Winkle Spruit, Natal, 28/5/15, Doidge, 9001.

3. *Asterina Combreti* Syd.

Engl. Bot. Jahrb. 1910, p. 264, on leaves of *Combretum taratense*, Kibwezi, British East Africa; Herb. Syd. and Berlin, Die Gattung *Asterina*, p. 63, pl. iii, fig. 8; vii, 7.

Hyphaster kutuensis (P. Henn.) in H. Baum, Ber. der Kunene-Zambesi-Exped. 1902, p. 169.

Asterina (*Dimerosporium*) *kutuensis* (P. H.) v. Höhn., Fragm. z. Mykol. xii, no. 599, on *Combretum Baumii*, East Africa.

Asterina Combreti var. *kutuensis* (P. Henn.) v. Höhn., Die Gattung *Asterina*, p. 63.

Plate XIII, fig. 8. Slides XXIII, 19, 20; XXXI, 16; XXXIII, 16.

Amphigenous, mostly epiphyllous, forming orbicular or indefinite spots 2-6 mm. diam.; mycelium delicate, undulating; hyphae light brown, branching irregularly and anastomosing, $3-4.5 \mu$ thick, less frequently up to 5μ thick, cells $16-20 \mu$ long; hyphopodia alternate briefly stipitate, $8-14 \times 4-5 \mu$, upper cell slightly lobed or curved. Thyriothecia gregarious, flattened-hemispherical, $140-180 \mu$ diam., composed of radiating hyphae about 3μ thick, cells rectangular $4-7 \mu$ long, the central ones almost cubical, cells longer towards the fimbriate margin; dehiscence stellate. Asci globose-ovate, $28-40 \times 28-32 \mu$, 8-spored, paraphysate. Spores conglobate, oblong, rounded at both ends, 1-septate, constricted, brown, $18-23 \times 8-11 \mu$, upper loculus frequently somewhat broader, epispore minutely verrucose at maturity. Pycnidia resembling the thyriothecia but smaller; conidia (*Asterostomella*) elliptical to pear-shaped, continuous, brown with a medial, hyaline band, $18-24 \times 9-13 \mu$.

On leaves of *Combretum Kraussii*, Woodbush, Zoutpansberg, 3/8/11, Doidge, 1773; Buccleuch, Natal, 20/4/16, J. M. Sim, 10152; Stella Bush, Durban, 19/4/18, Bottomley, 11378; Buccleuch, 23/3/16, Doidge, 9709.

On *Combretum*, sp., Winkle Spruit, Natal, 28/5/15, Doidge, 9004; Rikatli, Portuguese East Africa, Sept., 1918, Junod, 11731, 11732; Louis Trichardt, Transvaal, 8/4/19, Putterill, 11829.

Theissen (Die Gattung *Asterina*, p. 63) describes *A. Combreti* Syd. with hyphae $4-5 \mu$ thick, hyphopodia $8-10 \mu$ long and spores $20-24 \times 9-11 \mu$;

var. *kutuensis* (P. Henn.) v. Höhn. is distinguished from the type by its hyphae $3\text{--}3.5\ \mu$ thick, hyphopodia $10\text{--}13\ \mu$ long and spores $18\text{--}20 \times 8\text{--}9\ \mu$. Theissen had not seen the type specimen of *A. kutuensis*, but quoted von Höhnel's original description. I am unable to distinguish between these two forms; the spores vary from $18\text{--}23\ \mu$ in length and from $8\text{--}11\ \mu$ in breadth; sometimes the mycelium is fairly stout, $4\text{--}5\ \mu$ thick, with rather short hyphopodia ($8\text{--}10\ \mu$ long); in other cases the mycelium is more slender, $3\text{--}3.5\ \mu$ thick, with hyphopodia $10\text{--}13\ \mu$ long. Not infrequently all these characters can be met with on one leaf, and there is, within the limits indicated, considerable variation in the dimensions of the hyphae, hyphopodia and spores. I have therefore included all the collections examined in the species *A. Combreti* without attempting to distinguish varieties.

4. *Asterina Peglerae* Doidge, sp. nov.

Plate XIII, fig. 9. Slide XI, 20.

Hypophyllous, forming thin, spreading black areas of irregular form. Hyphae fuscous, very slender, $3.5\text{--}4\ \mu$ thick, branching irregularly and anastomosing; hyphopodia alternate or unilateral, $10\text{--}15 \times 6\text{--}10\ \mu$, stipitate, stipe usually cylindrical, equal in thickness to the hyphae, and from $3\text{--}10\ \mu$ long, but occasionally septate or gibbous (see *A. peraffinis*), terminal cell irregularly 2-3-lobed, and frequently uncinat. Thyriothecia numerous, scattered, light brown, flattened-hemispherical, $110\text{--}160\ \mu$ diam., composed of radiating hyphae $2.5\text{--}3\ \mu$ thick; these are not straight but more or less undulating; margin fimbriate; dehiscence irregular, then stellate. Asci paraphysate, sub-spherical, $45\text{--}50 \times 43\text{--}45\ \mu$, 8-spored. Spores conglobate, 2-celled, constricted, upper loculus larger, very opaque when mature, epispore ciliate, $23\text{--}28 \times 13\text{--}16.5\ \mu$.

On leaves of *Rhus*? sp., Kentani, 6/9/15, Pegler (Pegler, 2354), 9130.

The determination of the host is uncertain as Miss Pegler has never found this plant in flower. It is a small shrub with trifoliolate leaves.

The hyaline spores in the immature ascus of this species of *Asterina* are quite smooth, but on the spores which are just turning colour there are often bristles up to $3\ \mu$ long; the epispore is pronouncedly ciliate at maturity, but never has bristles so long as those on the ripening spore.

5. *Asterina tenuis* Wint.

Hedwigia, 1886, p. 94; Syll. Fung. ix, p. 389; Die Gattung Asterina, p. 116.

Plate XIV, fig. 10. Slides XVI, 17-20; XXIX, 7-8; XXXI, 20; XXXIV, 5-7; XXXVI, 2-5.

Amphigenous; mycelium effuse; hyphae light brown, very slender, anastomosing; hyphopodia alternate, mostly stipitate but some sessile

8–20 × 7–10 μ , distinctly 3–6-lobed, some almost palmate, others somewhat uncinat. Thyriothechia gregarious, often becoming angular through contact, otherwise flattened-hemispherical, fuscous, 85–130 μ diam., composed of radiating hyphae 2–3 μ thick, cells about 4 μ long; margin fimbriate, dehiscence stellate. Asci almost globose, sessile, 8-spored, 30–35 × 26–32 μ . Spores oblong, 1-septate, constricted, rounded at both ends, not infrequently asymmetrical, fuscous, 15–18 × 7–9 μ , lower locus slightly narrower. Pycnidia similar to the thyriothechia but slightly smaller; conidia (*Asterostomella*), oval to pyriform, fuscous with a hyaline medial band, 13–18 × 6–10 μ .

On leaves of *Claozylon* sp., Natal, Wood (Wood, 6458 b), 1534 b.

On *Dalechampia capensis*, Amanzimtoti, Natal, 10/7/11, Doidge, 1638; Winkle Spruit, Natal, 25/5/15, Doidge, 9003.

On *Acalypha decumbens*, Van Stadens Pass, 13/11/17, Doidge, 10862.

The type specimen (Wood 6458), consists of two different sets of leaves. The fungus on the leaves of *Claozylon* sp. corresponds with Winter's description of *A. tenuis*; the other leaves are apparently those of a *Capparis* sp., and the fungus, which is in very poor condition, resembles *A. celtidicola* var. *microspora*.

Evidently two sets of specimens have been confused, and this accounts for the fact that Theissen (Die Gattung Asterina), failed to find a species corresponding to *A. tenuis* on Wood's no. 6458.

6. *Asterina fimbriata* Kalch. & Cke.

Grevillea, ix, p. 33 c. tab. 138, f. 46; Syll. Fung. i, p. 41.

Asterina punctiformis Lév. var. *fimbriata*, Die Gattung Asterina, p. 67, T.V., fig. 19.

Plate XIV, fig. 11. Slides V, 6; XXIV, 20; XXV, 4.

Epiphyllous, mycelium radiating, irregularly branched, but branches frequently opposite and anastomosing very irregularly; hyphae light brown, undulating, 4–6 μ thick; hyphopodia alternate, stipitate, 8–12 × 6–8 μ , stipe cell short, terminal cell capitate or club-shaped, and usually slightly indented or 2–3-lobed. Thyriothechia gregarious, round, 130–170 μ diam., or oval, 170 × 140 μ ; composed of radiating hyphae 3.5–4.5 μ thick, cells 7–10 μ long; margin fimbriate, dehiscence stellate. Asci aparaphysate, 8-spored, ovate-spherical, 28–34 μ diam., or 36–48 × 26–28 μ . Spores conglabate, 1-septate, rounded at both ends, brown, deeply constricted, 18–22 × 8–10 μ , loculi sub-equal, or the upper locus slightly broader.

On leaves of *Sclerochiton harveyanus*, nr. Uitenhage, MacOwan (MacOwan, 1290); East London, 24/11/17, Doidge, 10910.

On *Hypoestes* sp., Wood, Natal (Wood, 608).

On *Plectronia ciliata*, East London, 24/11/17, Doidge, 10900.

7. *Asterina reticulata* Kalch. & Cke.

Grevillea, ix, p. 33; Syll. Fung. i, p. 40.

Asterostomella reticulata (K. & Cke.) v. Höhn., Fragm. z. Myk. 493.

Plate XIV, fig. 12. Slides XXVI, 7-8.

Amphigenous, forming black, carbonaceous, sub-orbicular spots; or spreading, chiefly along the veins and leaf margins. Mycelium spreading, reticulate; hyphae light brown, 5-6 μ thick, straight, cells 15-30 μ long; branches usually opposite, anastomosing; hyphopodia alternate or unilateral, briefly stipitate, club-shaped, hooked or slightly lobed, 7-13 \times 6-8 μ . Thyriothecia flattened-hemispherical, composed of radiating hyphae 3-3.5 μ thick, cells 3.5-4 μ long, cubical; margin fimbriate, dehiscence irregular-stellate. Asci ovate, sessile, aparaphysate, 45-50 \times 30-33 μ . Spores conglobate, 1-septate, constricted, brown, smooth, 20-23 \times 10 μ ; loculi sub-equal or upper loculus slightly broader, each cell almost spherical. Pycnidia similar to the thyriothecia but smaller, 100-150 μ diam.; conidia brown with a medial hyaline band, ellipsoid or pyriform, 16-20 \times 7-10 μ .

On leaves of *Olinia cymosa*, Boschberg, Cape Province, 1877, MacOwan (MacOwan, 1336, Rabh.-Wint. Fung. Eur. 3337), *Asterostomella* stage only.

On *Olinia* sp., Barberton, 18/1/91, Galpin (Galpin, 1275).

MacOwan's specimen shows only the conidial stage, and was on that account referred by v. Höhnelt to the genus *Asterostomella*. I have not succeeded in collecting this fungus myself but was fortunate in finding the thyriothecia and ascospores on a specimen of *Olinia* in the Galpin herbarium.

8. *Asterina uncinata* Doidge, sp. nov.

Plate XIV, fig. 13. Slides X, 15-16.

Hypophyllous, effuse; mycelium light brown, delicate, branching irregularly and anastomosing; hyphae undulating, 5-6 μ thick, cells 26-33 μ long; hyphopodia alternate, unilateral or opposite, stipitate, 20-40 μ long, stipe 1-3-celled, 7-30 μ long, cylindrical, equal in thickness to the hyphae, straight, curved, or abruptly geniculate, occasionally bearing two terminal cells; terminal cell club-shaped or cylindrical, straight or uncinuate, the curve being in the same direction as, or in the opposite direction to that of the stipe, occasionally sub-lobed. Thyriothecia large, rather pale and covered with a network of hyphae, flattened-hemispherical, 200-280 μ diam., composed of radiating hyphae 3-5 μ thick—these are straight except at the margin, where they become tortuous; cells 3.5-7 μ long; dehiscence by a central pore, which develops into a stellate fissure; margin not fimbriate. Asci aparaphysate, spherical or ovate, 42-50 \times 40-45 μ . Spores smooth, dark brown, opaque, 30-34 \times 16-20 μ , deeply constricted; each loculus ovoid; upper loculus 18-20 μ broad, lower loculus 14-16 μ broad.

On leaves of *Rhamnus prinoides*, Brander's High Forest, Victoria East, 12/8/15, v. d. Bijl, 9463; on the same leaves as *A. rhamnicola*.

12. *Asterina delicata* Doidge, sp. nov.

Plate XIV, fig. 14. Slide XXXI, 10.

Epiphyllous, effuse, forming thin blackish spots up to 8 mm. diam. Mycelium spreading, delicate; hyphae slender, light brown, $3\text{--}3.5\ \mu$ thick, cells $20\text{--}24\ \mu$ long, branching irregular; hyphopodia alternate, 1-celled, asymmetrical, usually angular or sub-lobed, $6\text{--}7\ \mu$ high by $6\text{--}10\ \mu$ broad. Thyriothecia gregarious or scattered, flattened-hemispherical, $100\text{--}130\ \mu$ diam., composed of radiating hyphae $3\ \mu$ thick, cells almost cubical, $3\text{--}3.5\ \mu$ long; margin not markedly fimbriate; dehiscence at first by a central pore, then irregular. Asci paraphysate, sessile, ovate or spherical, $26\text{--}33 \times 33\text{--}40\ \mu$. Spores conglobate, light brown, 1-septate, constricted, broadly rounded at both ends, $20\text{--}22 \times 10\text{--}12\ \mu$, cells sub-equal, or upper loculus slightly broader. Pycnidia similar to the thyriothecia but smaller, $70\text{--}100\ \mu$ diam. Conidia dark brown, continuous, elliptical to ovate, $20\text{--}22 \times 12\text{--}15\ \mu$.

On leaves of *Trimeria alnifolia*, Mayville, Durban, 22/7/15, Wood, 9062.

10. *Asterina Grewiae* Cke.

Grevillea, x, p. 130; Ann. Myc. x, p. 189; Die Gattung Asterina, p. 76.

Plate XIV, fig. 15. Slides XXVI, 13; XXIX, 13; XXXIII, 1.

Amphigenous, mostly epiphyllous; mycelium effuse, delicate, irregularly branched, and anastomosing to form a network; hyphae slender, light brown, $3.5\text{--}4\ \mu$ thick, undulating; cells $15\text{--}20\ \mu$ long; hyphopodia alternate, unilateral or occasionally opposite, 1-celled, finger or flask-shaped, sometimes sub-lobed, $8\text{--}10 \times 3.5\text{--}4\ \mu$. Thyriothecia numerous, flattened-hemispherical, $100\text{--}130\ \mu$ diam., formed of radiating hyphae about $3\ \mu$ thick, with cells $3\text{--}5\ \mu$ long; margin not fimbriate; dehiscence by an irregular-stellate fissure. Asci paraphysate, 8-spored, spherical, $20\text{--}24\ \mu$ diam. Spores conglobate, brown, 1-septate, smooth, constricted, $20\text{--}22 \times 10\text{--}12\ \mu$, upper loculus broader and almost spherical. Pycnidia similar to the thyriothecia but smaller, $50\text{--}65\ \mu$ diam.; conidia continuous, ovate-elliptical, rounded at both ends, $18\text{--}20 \times 11\text{--}13\ \mu$, brown without medial band.

On leaves of *Grewia lasiocarpa*, Inanda, Natal, 1879, Wood (Wood, 639); Kentani, 25/8/17, Pegler (Pegler, 2436), 10993; Woodville Forest, George, 11/11/17, Doidge, 11018.

11. *Asterina Trichiliae* Doidge, sp. nov.

Plate XIV, fig. 16. Slides XXXIV, 11; XLVII, 11.

Epiphyllous, forming thin, scattered, sub-circular spots up to 6 mm. diam. Hyphae brown, straight, $4\text{--}6\ \mu$ thick, branches opposite, anastomosing, often at right angles to the hyphae; hyphopodia frequently opposite,

finger- or flask-shaped, sessile, $6-10 \times 4-5 \mu$. Thyriothecia scattered, flattened-hemispherical, $190-220 \mu$ diam., formed of radiating hyphae $3-3.5 \mu$ thick, opaque in the centre, more translucent towards the fimbriate margin; dehiscence stellate. Asci paraphysate, 8-spored, ovate or subspherical, $40-46 \times 43-50 \mu$, embedded in a yellowish mass of mucilaginous matter. Spores conglobate, 1-septate, constricted, $25-27 \times 12-13 \mu$, dark brown, opaque when mature and minutely scabrous, upper loculus slightly broader.

On leaves of *Trichilia dregeana*, Winkle Spruit, Natal, 28/5/16, Doidge, 9006.

On *Trichilia emetica*, Louis Trichardt, Zoutpansberg, 8/4/19, Putterill, 11833.

12. *Asterina raripoda* Doidge, sp. nov.

Plate XIV, fig. 17. Slide XXIV, 9.

Epiphyllous, forming thin black spots $3-5$ mm. diam.; mycelium poorly developed, branching irregularly and occasionally anastomosing; hyphae pale-fuscous, $3.5-5 \mu$ thick, frequently septate and somewhat sinuous, cells mostly $10-15 \mu$ long; hyphopodia rare, alternate, 1-celled, hemispherical, $4-5 \mu$ high and $6-7 \mu$ broad. Thyriothecia scattered or confluent in small groups, flattened-hemispherical, arising at the tips of secondary hyphae and at first fan-shaped, or, less frequently, medial and round from the start, $150-200 \mu$ diam., at first papillate, then dehiscing by a stellate fissure; margin irregularly crenulate, but not fimbriate. Asci paraphysate, cylindrical-clavate to ovate, not tunicated, 8-spored, $40-52 \times 16-24 \mu$. Spores conglobate, 2-celled, brown, slightly constricted, smooth, $15-18 \times 7-10 \mu$; upper loculus broader, spherical; lower loculus ellipsoid.

On leaves of *Ansellia africana*, Zululand, April 1913, Franks, 6687.

13. *Asterina ferruginosa* Doidge, sp. nov.

Plate XIV, fig. 18. Slides XXXIV, 1-2; XXXIX, 13.

Epiphyllous, forming thin, black, carbonaceous spots up to 8 mm. diam., frequently coalescing to form irregular blotches. Hyphae brown, slender, $4-6 \mu$ thick, branches usually opposite, anastomosing, cells $23-27 \mu$ long; hyphopodia alternate or unilateral, sessile, hemispherical or sub-globose, $6-8 \mu$ high and $8-10 \mu$ broad; there are occasional stipitate hyphopodia, chiefly in the neighbourhood of the thyriothecia; they are 2-celled, $12-13 \times 6-7 \mu$, the stipe cell being about 6μ long. Thyriothecia numerous, scattered, or confluent in small groups, flattened-hemispherical, $160-190 \mu$ diam., ferruginous, formed of radiating hyphae $3-3.5 \mu$ thick; margin densely fimbriate; dehiscence stellate. Asci paraphysate, 8-spored, sub-spherical, $33-37 \mu$ diam., embedded in a dirty yellow mass of mucilaginous matter. Spores conglobate, 1-septate, brown, slightly constricted, smooth, $23-26 \times 11-12.5 \mu$; upper loculus slightly broader.

On leaves of *Cussonia umbellifera*, Woodbush, Zoutpansberg Dist., 3/8/11, Doidge, 1774.

On *Cussonia spicata*, Sea View, Durban, 1/10/17, v. d. Bijl, 11360.

14. *Asterina rhamnicola* Doidge, sp. nov.

Plate XV, fig. 19. Slides X, 14-18; XXXIII, 3.

Epiphyllous, forming thin, carbonaceous, more or less orbicular, spots up to 5 mm. diam. Mycelium delicate, radiating; hyphae straight, brown, 6-7 μ thick; branches alternate or opposite, anastomosing; cells mostly 25-30 μ long; hyphopodia alternate or unilateral, sessile, shortly and broadly cylindrical or sub-hemispherical, 6-10 \times 6-7 μ . Thyriothecia not numerous, scattered, conico-hemispherical, paler than the mycelium, 225-280 μ diam., formed of radiating hyphae 3-5 μ thick; margin not fimbriate; dehiscence by the irregular rupture of the central cells. Asci paraphysate, broadly elliptic to ovate, 8-spored, 45-50 \times 23-33 μ . Spores conglobate, 1-septate, fuscous, slightly constricted, 23-25 \times 9-12 μ , upper loculus larger.

On leaves of *Rhamnus prinoides*, Woodbush, Zoutpansberg, 4/8/11, Doidge, 1752; Kentani, 10/4/15, Pegler (Pegler, 2315), 9068; Brander's High Forest, Victoria East, 12/8/15, v. d. Bijl, 9463.

15. *Asterina Hendersoni* Doidge, sp. nov.

Plate XV, fig. 20. Slides XLVII, 16-17.

Amphigenous, forming black spots up to 3 mm. diam. Mycelium brown, branching irregularly and anastomosing. Hyphae 5-6 μ thick, tortuous, sub-torulose, very frequently septate, cells 6-8 μ long; hyphopodia hemispherical, or somewhat angular or flattened, alternate, 3.5-6 μ diam. Thyriothecia flattened-hemispherical, scattered, 150-200 μ diam., formed of rather tortuous, radiating hyphae about 3.5 μ thick; margin coarsely fimbriate; dehiscence by an irregular rupture of the central cells. Asci paraphysate, 8-spored, broadly ellipsoid to ovate, sessile or very briefly pedicellate, 45-50 \times 26-33 μ , do not stain blue with iodine. Spores brown, 1-septate, constricted, 23-25 μ long; each cell sub-globose; upper loculus 13-13.5 μ broad, lower loculus 10-11 μ broad. Pycnidia similar to the thyriothecia but smaller, 120-150 μ diam.; conidia brown with a medial hyaline band, ovate to ellipsoid, 23-27 \times 10-13 μ .

On leaves of *Ilex capensis*, Hogg's Back, 15/1/18, J. & M. Henderson, 11341, 11342.

16. *Asterina opaca* Syd.

Ann. Myc. x, p. 38; Die Gattung *Asterina*, p. 113.

Plate XV, fig. 21. Slides XXIII, 12; XLII, 9.

Epiphyllous, forming black, orbicular spots 1-3 mm. diam. Hyphae

short, but very much branched and anastomosing, chestnut brown, $5-7\ \mu$ thick, very closely interwoven; hyphopodia small, sessile, 1-celled, rounded at the apex or rarely slightly attenuated, alternate or opposite, $9-11\ \mu$ long, $5-6\ \mu$ broad. Thyriothecia often 1 or 2 in each spot, in the larger spots as many as 10, hemispherical, $150-250\ \mu$ diam., dehiscing irregularly, black, opaque, somewhat fimbriate. Asci ovate to globose, slightly thickened at the apex, paraphysate, $50-70 \times 35-46\ \mu$, 8-spored. Spores conglobate, ellipsoid, broadly rounded at both ends, septate, deeply constricted, cells equal, smooth, $26-28 \times 13-14\ \mu$.

On leaves of *Chrysophyllum natalensis*, Amanzimtoti, Natal, 10/7/11, Doidge, 1663.

On *Chrysophyllum* sp., Buccleuch, Natal, 10/7/18, Doidge, 11555.

17. *Asterina robusta* Doidge, sp. nov.

Plate XV, fig. 22. Slides VI, 15, 19, 20.

Epiphyllous, forming black, carbonaceous spots up to 5 mm. diam.; these are often so numerous as to become confluent and form irregular black areas on the leaf surface. Mycelium dark brown, radiating; hyphae $6-7\ \mu$ thick, some of the cells swollen, $9-10\ \mu$ thick; cells about $20\ \mu$ long; branches opposite or alternate, usually somewhat narrowed at junction with main hypha; hyphopodia usually unilateral, sometimes alternate, 1-celled sub-hemispherical, $6-6.5 \times 6.5-7\ \mu$. Thyriothecia numerous, $300-400\ \mu$ diam., crowded, flattened-hemispherical when solitary, but more frequently confluent in small groups and becoming angular by lateral compression, opaque, almost black; composed of radiating hyphae about $5\ \mu$ thick; dehiscence by an irregular fissure, the cells breaking away from the centre outwards. Asci 8-spored, obovate, $65-75 \times 45-55\ \mu$, thickened round the apex; there are no true paraphyses, but the asci are surrounded by a spongy tissue of small greenish yellow cells, which decompose into the dirty yellow mucilaginous mass in which the asci are embedded at maturity. Spores conglobate, $35-40 \times 18-20\ \mu$, very dark brown, 1-septate, constricted, smooth, upper loculus slightly broader, each cell sub-spherical.

On leaves of *Pittosporum viridiflorum*, Mossel Bay, 22/7/15, Pole Evans, 9066.

18. *Asterina erysiphoides* Kalch. & Cke.

Grevillea ix, p. 32, t. 137, fig. 12; Syll. Fung. i, p. 47; Ann. Myc. x, p. 16.

Plate XV, fig. 23. Slides XXIII, 17-18; XXXII, 11.

Epiphyllous, forming black, sooty spots up to 6 mm. diam. Mycelium spreading, delicate; hyphae brown, $3.5-5\ \mu$ thick, much branched and anastomosing freely; hyphopodia alternate, sessile, 1-celled, erect or hooked, irregularly 3-5-lobed, $7-13\ \mu$ high and $5-10\ \mu$ broad. Thyriothecia flattened-

hemispherical, sub-opaque, 120–130 μ diam., composed of radiating hyphae 3–3.5 μ thick, central cells almost cubical, about 4 μ long; dehiscence stellate, margin fimbriate. Asci aparaphysate, almost spherical, 30–34 μ diam. Spores brown, 1-septate, constricted, rounded at both ends, 20–23 \times 10–12 μ , upper loculus broader, epispore verrucose at maturity. Pycnidia similar to the thyriothechia but smaller, 80–100 μ diam.; conidia ovate to pyriform, continuous, brown with an ill-defined, light, medial band, 16–20 \times 10–14 μ .

On leaves of *Jasminum tortuosum*, MacOwan 1139. MacOwan's No. 1139 in the herbarium of the South African Museum, Capetown, is *Puccinia exhauriens* Thüm., and I could find on the leaves no trace of an *Asterina* mycelium. Theissen (Ann. Myc. x, p. 16) writes of the specimen in the Kew Herbarium: "Das Original enthält eine unreife *Asterina* mit hellbraunlichem Myzel, dessen Hyphen 4–5 μ dick sind und abwechselnde 6–8 hohe, meist drei-lappige Hyphopodien tragen. Die unreifen Gehäuse enthalten noch keine Schläuche, nur braune, hyalin gegurtelte sog. Stylosporen von 18–20 μ Länge und 10–12 μ Breite ('sporidiis ellipticis, continuis, atrofusis 18–20 \times 10' in der Originaldiagnose) Die Art ist zu streichen." Two more recent collections on *Jasminum* spp., however, show abundant thyriothechia and mature spores, and as the mycelium and conidia correspond with the above description I have re-described *A. erysiphoides* from these.

On *Jasminum multipartitum*, Springfield, Natal, 14/7/15, Wood, 9018.

On *Jasminum angulare*, Kentani, 8/11/15, Pegler (Pegler, 1868), 9161.

On *Jasminum* sp., Alice, C.P., 18/11/17, Doidge, 11978.

19. *Asterina Balansae* (Speg.) Th.

Die Gattung *Asterina*, p. 88.

Seynesia Balansae Speg. F. Guar. i, No. 297; ii, No. 130; Syll. Fung. ix, p. 1065.

var. *africana* Sacc.

Hedwigia, 1899, p. (133); Syll. Fung. xvi, p. 640; Die Gattung *Asterina*, p. 88.

Plate XV, fig. 24. Slide XXIII, 4.

Epiphyllous, forming opaque black spots 3–5 mm. diam.; these are often so numerous that they coalesce. Mycelium dense, irregularly branched; hyphae brown, sinuous, 4–6 μ thick, cells 12–15 μ long; hyphopodia alternate or unilateral, sessile, lobed, 4 μ high and 7–8 μ broad. Thyriothechia flattened-hemispherical, 100–150 μ diam., composed of radiating hyphae 3–3.5 μ thick, dehiscence stellate or irregular. Asci aparaphysate, 8-spored, spherical, 25–40 μ diam., or ellipsoid, 28–45 \times 18–24 μ . Spores conglobate, brown, 1-septate, constricted, 17–22 \times 8–10 μ ; the upper cell spherical and broader than the lower; epispore minutely verrucose at maturity.

On leaves of *Rubus rigidus*, Natal, Wood (Wood, 6464), 9507.

20. *Asterina Excoecariae* Doidge, sp. nov.

Plate XV, fig. 25. Slides XIII, 11; XXXIV, 3.

Amphigenous; thin, carbonaceous, not forming orbicular spots, but irregular areas up to 8 mm. diam. Mycelium effuse; hyphae delicate, rather pale, somewhat undulate, $3\text{--}3.5\ \mu$ thick, cells about $16\ \mu$ long, branches opposite, anastomosing; hyphopodia sessile, alternate, or unilateral, various in shape, usually with 2-3 broad lobes, $6\text{--}7 \times 6\text{--}8\ \mu$. Thyriothecia scattered, flattened-hemispherical, $100\text{--}120\ \mu$ diam., composed of radiating hyphae $2.5\text{--}3\ \mu$ thick; dehiscence stellate. Asci paraphysate, evanescent, 8-spored, sub-spherical, sessile, about $35\text{--}40\ \mu$ diam. Spores conglobate, 1-septate, brown, constricted, $23\text{--}27 \times 12\text{--}13.5\ \mu$, the upper loculus larger; epispore scabrous at maturity. Pycnidia similar to the thyriothecia but smaller, $60\text{--}70\ \mu$ diam.: conidia ovate, brown, with or without lighter, but not hyaline, medial band, $20\text{--}24 \times 13\text{--}17\ \mu$.

On leaves of *Excoecaria* sp., Winkle Spruit, Natal, 28/5/15, Doidge, 9009.21. *Asterina undulata* Doidge, sp. nov.

Plate XV, fig. 26. Slide XXXI, 12.

Epiphyllous, forming minute black spots 1-3 mm. diam. Hyphae pale-fuscescent, undulating in more or less regular waves, $5\text{--}6.5\ \mu$ thick, not much branched, occasionally anastomosing, cells $18\text{--}22\ \mu$ long; hyphopodia alternate, 1-celled, broader than long, $5\text{--}6.5\ \mu$ high and $7\text{--}10\ \mu$ broad, irregularly lobed and cut, many almost palmate. Thyriothecia formed at the tips of secondary hyphae, the immature thyriothecia are fan-shaped; mature thyriothecia flattened-hemispherical, gregarious, often becoming slightly angular by contact; margin not fimbriate; radiating hyphae $2.5\text{--}3\ \mu$ thick, cells $4\text{--}6\ \mu$ long. Asci paraphysate, 8-spored, slightly thickened round the apex, ovate, $20\text{--}24 \times 17\text{--}20\ \mu$. Spores conglobate, narrow-ovate, brown, 1-septate, constricted, $13\text{--}15 \times 6\text{--}8.5\ \mu$, broadly rounded at both ends, upper loculus slightly broader.

On leaves of *Viola abyssinica*, Woodbush, Zoutpansberg, 4/8/11, Doidge, 1769.

Near *A. Veronicae*, from which it differs in the size and form of the hyphopodia. In *A. Veronicae* there is a fairly broad sinus between the lobes; in the present species the lobes are closely folded together, so that only one wall is visible between the two. There is also a difference in the size of the spores.

22. *Asterina polythyria* Doidge, sp. nov.

Plate XV, fig. 27. Slide XXIV, 8.

Mostly epiphyllous, colonies black, crustaceous, 1-4 mm. diam. Mycelium forming a radiating fringe round the very numerous, closely-packed thyriothecia and pycnidia. Hyphae brown, sinuous, branches numerous, frequently

opposite and anastomosing; hyphopodia sessile, broader than long, lobed, most frequently 2-3-lobed, 5-7 μ high and 6-10 μ broad. Thyriothecia opaque, densely crowded, flattened-hemispherical, 150-170 μ diam., with stellate dehiscence; or oblong, 190-200 \times 140 μ , dehiscing by a lineal fissure. Asci cylindrical-ovate, aparaphysate, 8-spored, 26-40 \times 20-24 μ , slightly thickened round the apex. Spores conglobate, 1-septate, brown, slightly constricted, 16-20 \times 67 μ , smooth, the upper loculus somewhat broader. Pycnidia similar to the thyriothecia but smaller, 65-120 μ diam.; conidia brown with a hyaline band, continuous, ovate to pyriform, 16-21 \times 6-10 μ .

On leaves of *Oxyridicarpus natalensis*, Tongaat, Natal, 12/9/13, v. d. Bijl, 6949.

Sub-genus II. CLYPEOLASTER Th.

Die Gattung Asterina, p. 6.

Thyriothecia with basal membrane, asci aparaphysate. The basal membrane is a blue-grey or grey-green disk formed of radiating hyphae, and apparently reproduces the structure of the thyriothecial membrane.

a. Hyphopodia 2-celled.

a. Stipe cell gibbous 23. *A. peraffinis*.

b. Stipe cell cylindrical.

1. Hyphopodia lobed, 9-14 μ high.

i. Spores 16-18 μ long 24. *A. celtidicola*
var. *microspora*.

ii. Spores 20-23 μ long 25. *A. ? vagans*.

2. Hyphopodia not lobed, 12-20 μ high 26. *A. sphaerascas*.

Hyphopodia 1-celled.

a. Hyphopodia not lobed 27. *A. loranthicola*.

b. Hyphopodia lobed.

1. Spores smooth 28. *A. clausenicola*.

2. Spores verrucose.

i. Spores 18-20 μ long 29. *A. diplocarpa*.

ii. Spores 15-18 μ long 30. *A. tertia* var.
africana.

23. *Asterina peraffinis* Speg.

Fung. Puig. 355; Syll. Fung. ix, p. 392.

On living leaves of an *Asclepiadaceae*, Apiahy, São Paulo; Museo Nacional, Buenos Aires. On a similar host, São Leopoldo, Rio Grande do Sul, Herb. Theissen.

Asterina pseudopelliculosa Speg. var. *peraffinis* (Speg.) Th. Die Gattung Asterina, p. 104.

Plate XVI, fig. 28. Slides VIII, 15, 20, 18, 19.

Hypophyllous; mycelium slender, undulating, densely reticulate; hyphae

brown, $3.5-5\ \mu$ thick, branches opposite or alternate, anastomosing; hyphopodia alternate or unilateral, 2-celled, occasionally sessile, 1-celled, $10-15 \times 8-12\ \mu$, most frequently palmately 3-4-lobed and obliquely septate between the first and second lobes; thus the stipe cell is gibbous and the terminal cell has 2-3 blunt lobes. Thyriothecia $100-160\ \mu$ diam., hemispherical, dehiscing by an irregular central fissure, which later becomes stellate; composed of radiating cells, $3-3.5\ \mu$ diam., margin fimbriate. Asci paraphysate, spherical to obovate, $30-50 \times 25-30\ \mu$, 8-spored. Spores conglobate, brown, oblong, $18-22 \times 7-10\ \mu$, upper loculus sub-globose, lower loculus narrower. Pycnidia similar to the thyriothecia but smaller, about $70\ \mu$ diam.; conidia continuous, brown without a hyaline band, ovate to pyriform, $17-20 \times 6-10\ \mu$.

On leaves of *Tylophora Flanaganii*, Lemana, Zoutpansberg, 14/8/11, Doidge, 1804; Hoek-van-helbosch, Zoutpansberg, 7/1/06, Burt Davy, 1228; Brander's High Forest, Victoria East, 14/8/15, v. d. Bijl, 9458.

Theissen (Die Gattung *Asterina*) makes this a variety of *A. pseudopelliculosa*, from which it differs in the 2-celled hyphopodia, on the grounds that in the Brazilian specimens of *A. peraffinis* 1-celled hyphopodia are also found. In my specimens 1-celled hyphopodia are rare or absent, and it appears to me that the fact that the majority of the hyphopodia are 2-celled is sufficient to separate this species from *A. pseudopelliculosa*, where they are constantly 1-celled. Theissen also mentions f. *africana* = *Asterina Strophanthi* P. Henn., Engl. Bot. Jahrb. 38, p. 125, on *Strophanthus hispidus*, Togo, Africa, Rehm. Ascom. 1624, Herb. Berlin. This form, which is not represented in the National Herbarium, has some 1-celled and some 2-celled hyphopodia, and is an intermediate form between *A. peraffinis* and *A. pseudopelliculosa*.

24. *Asterina celtidicola* P. Henn.

Hedwigia, 1905, p. 64; Syll. Fung. xvii, p. 846; Die Gattung *Asterina*, p. 94, on leaves of *Celtis* sp., Rio Jurua, Amazonas; Herbar. Berlin.

Var. *microspora* Doidge, var. nov.

Plate XVI, fig. 29. Slides XXIV, 9; XXXVI, 15; XL, 6; XLII, 3, 4.

Mostly epiphyllous; hyphae brown, undulate, $3.5-5\ \mu$ thick, with cells $20-24\ \mu$ long; branching irregularly to form a network of anastomosing hyphae; hyphopodia alternate, stipitate, straight or curved, the terminal cell lobed, $9-13\ \mu$ high and $6-10\ \mu$ broad. Thyriothecia $85-100\ \mu$ diam., hemispherical, dehiscence stellate, margin fimbriate; composed of radiating hyphae $3-3.5\ \mu$ thick, cells $4-5\ \mu$ long. Asci ovate to globose, $23-30 \times 26-33\ \mu$, paraphysate, 8-spored, thickened round apex, not stained blue by iodine. Spores dark brown, epispore strongly echinulate, rounded at both ends, 2-celled, constricted, $16-18 \times 8-9\ \mu$, rarely $20\ \mu$ long, upper loculus

very slightly broader. Pycnidia similar to the thyriothecia but smaller, 70–100 μ diam., conidia brown with a medial hyaline band, continuous, oval to ovate, 14–20 \times 8–10 μ .

On leaves of *Maerua* sp., Stella Bush, Durban, 1/7/14, Franks, 8405; Amanzimtoti, Natal, 10/7/11, Doidge, 1683.

On leaves of *Maerua pedunculosa*, Stella Bush, Durban, 7/4/18, Bottomley, 11376.

On *Oncoba Kraussiana*, Stella Bush, Durban, 23/9/17, v. d. Bijl, 11361; 8/4/18, Bottomley, 11382.

Var. *microspora* differs from the type, and also from var. *Capparidis* (*Asterina Capparidis* Syd. et Butler, Ann. Myc. 1911, p. 390, on leaves of *Capparis*, Madras, India; Butler, 1179, Herb. Sydow.) chiefly in the size of the spores and asci. Var. *Capparidis* differs from the type in the short cubical cells composing the thyriothecium, which are not so delicate as those of the type, and in the somewhat stouter mycelium, the hyphae being 4.5–5.5 μ thick. The spores resemble those of the type. Var. *microspora* agrees very closely with the type in the form of the mycelium, but differs in the size of the asci and spores.

25. *Asterina* ? *vagans* Speg.

Fung. Guar. no. 127; Syll. Fung. ix, p. 390; Die Gattung *Asterina*, p. 95.

Pl. XVI, fig. 30. Slides XI, 10, 15; XLIV, 18.

Epiphyllous, effuse; hyphae radiating, brown, about 5 μ thick, branches distant, often opposite, cells usually 25–30 μ long; hyphopodia alternate or unilateral, 9–14 \times 8–11 μ , briefly stipitate, stipe cell 3.5–6 μ long, terminal cell asymmetrical, more or less hooked, most frequently unequally 2-lobed or 3-lobed. Thyriothecia scattered, flattened-hemispherical, 120–180 μ diam., margin fimbriate; dehiscence by a stellate fissure; composed of radiating hyphae 3–3.5 μ thick, central cells cubical, 3.5–4.5 μ long. Asci apophysate, embedded in a dirty-yellow mass of mucilaginous matter, ovate, 33–37 \times 33–35 μ . Spores conglobate, brown, 2-celled, loculi sub-equal, slightly constricted, 20–26 \times 10–13 μ , verrucose when mature. Pycnidia 50–60 μ diam.; conidia brown with an obscure medial band, oval to pyriform, 15–18 \times 10–11 μ .

On leaves of *Rinorea ardisiaeflora*, Buccleuch, Natal, 20/5/15, Doidge, 9704; 17/7/18, Doidge, 11581.

This should perhaps be described as a variety of *A. vagans*, the hyphae composing the thyriothecium are somewhat more slender than the type, and the asci do not stain blue with iodine; but my material of this species is very scanty, and I hesitate to describe it as a distinct variety until I have examined further collections.

26. *Asterina sphaerasca* Thüm.

Fung. Austro-Afric. 119; Syll. Fung. i, p. 40; Die Gattung Asterina, p. 115. "On leaves of *Capparis Guienzii*, Olifants Hoek, Uitenhage Dist."

Plate XVI, fig. 31. Slides XXIII, 11; XXIV, 13.

- Epiphyllous, effuse; mycelium brown, consisting of sinuous hyphae 5-6 μ thick, cells 24-30 μ long, branching irregular, hyphae anastomosing to form a network; hyphopodia 2-celled, not lobed, erect, straight or uncinat, opposite or alternate, 12-20 \times 5-6 μ . Thyriothecia numerous, opaque, hemispherical, 130-170 μ diam., composed of radiating hyphae 3-4 μ thick, central cells 3.5-4 μ long, peripheral cells longer, margin fimbriate. Asci aparaphysate, spherical or ovate, 35-45 μ diam., 8-spored, not stained blue by iodine. Spores conglobate, 2-celled, constricted, 20-24 \times 10-12 μ , dark brown when mature and strongly echinulate, rounded at both ends, cells sub-equal. Pycnidia similar to thyriothecia but smaller, 100-120 μ diam., conidia ovate, brown, 20-25 \times 12-15 μ .

On leaves of *Capparis citrifolia*, Winkle Spruit, Natal, 28/5/15, Doidge, 9010.

I think there can be no doubt that this is the fungus collected by von Thümen, although I have not seen the type specimen. It is the only species which agrees with his description, and the host belongs to the same genus *Capparis*. *A. celtidicola* var. *microspora* on *Maerua* differs in the size of the spores and asci, and in the form of the hyphopodia.

Theissen, judging only by the imperfect description (Syll. F. i, p. 40), and not having seen the type, places this species amongst those imperfectly known, and remarks on its similarity to *A. Capparidis*. From this species (or variety, *A. celtidicola* var. *Capparidis*), *A. sphaerasca* differs in the form of the hyphopodia, which are taller and not lobed.

27. *Asterina loranthicola* Syd.

Ann. Myc. xii, 3, p. 266.

Plate XVI, fig. 32. Slides XXV, 9, 16; XXVI, 19, 20.

Amphigenous; mycelium spreading, composed of hyphae which are straight or nearly straight, brown, 4-6 μ thick, and irregularly branched; hyphopodia not at all numerous, alternate, sessile, 1-celled, cylindrical to obovate, often uncinat, 9-11 μ long, 5-6 μ broad. Thyriothecia densely aggregated, always flattened-hemispherical, 109-160 μ diam., composed of straight, radiating hyphae 3.5-5 μ thick, cells rectangular, up to 7 μ long; margin fimbriate; thyriothecial membrane easily separating into its component parts. Asci aparaphysate, ovate to globose, 30-38 \times 24-30 μ , 8-spored. Spores ellipsoid-oblong, 1-septate, brown, rounded at both ends, 20-24 \times 8-11 μ , epispore ciliate, upper loculus often slightly broader.

Pycnidia similar to the thyriothechia but smaller; conidia elliptic-pyriform, brown, with or without a hyaline band, $15-22 \times 9-11 \mu$.

On leaves of *Loranthus* sp., Quelimane, Portuguese East Africa, 14/9/17, Pole Evans, 7385.

On leaves of *Loranthus Dregei*, 8/3/15, Pegler (Pegler, 2302), 8863.

28. *Asterina clausenicola* Doidge, sp. nov.

Plate XVI, fig. 33. Slides VI, 16, 17; XLV, 7.

Amphigenous, mostly epiphyllous, effuse, forming a thin, spreading, carbonaceous layer frequently almost covering the upper surface of the leaf. Mycelium delicate, consisting of pale-fuscon hyphae $3-3.5 \mu$ thick, undulating, frequently branching and anastomosing, hyphopodia alternate or unilateral, occasionally opposite, sessile, 1-celled, $6-7 \mu$ high and $9-10 \mu$ broad, deeply 3-5-lobed, each lobe flattened or bilobulate, narrowing suddenly into a base $3-3.5 \mu$ thick. Thyriothechia scattered, flattened-hemispherical, $110-140 \mu$ diam., formed of radiating hyphae $2.5-3 \mu$ thick, with cells $3-3.5 \mu$ long; dehiscing by a stellate fissure; margin fimbriate. Asci paraphysate, 8-spored, broadly ovate or spherical, sessile, broadly rounded and thickened at the apex, $27-30 \times 23-24 \mu$. Spores conglobate, fuscous, smooth, 1-septate, slightly constricted, $19-20 \times 6.5-8 \mu$, upper loculus usually slightly larger. Pycnidia very numerous, similar to the thyriothechia but smaller, $50-60 \mu$ diam., conidia brown with a hyaline band, continuous, ovate to ellipsoid, $15-18 \times 8.5-11.5 \mu$.

On leaves of *Clausena inaequalis*, Hilton Road, Natal, 21/7/18, Doidge, 11606.

Asterostomella stage only: on *Clausena inaequalis*, Woodbush, Zoutpansberg, 4/8/11, 1754; Buccleuch, Natal, 24/4/16, J. M. Sim, 10149.

29. *Asterina diplocarpa* Cke.

Grevillea, x (1882), p. 129; Syll. Fung. ix, p. 381; Die Gattung *Asterina*, p. 106.

On leaves of *Sida cordifolia*, Inanda, Natal, Herb. Kew, Wood, 601; on *Sida carpinifolia*, São Leopoldo, Rio Grande do Sul, Herb. Theissen; Decades F. Brasil, 54 sub *A. peraffinis*; Rick. F. austro-amer. 325; Ule 673 on *Croton*, Rio de Janeiro, Herb. Berlin and Pazschke sub *A. peraffinis*.

Asterina similis Cke., Grevillea x, p. 130; Syll. Fung. l. cit., on *Sida rhombifolia*, Inanda, Natal, Herb. Kew, Wood, 544, "socio *A. diplocarpa*."

Asterina Sidae Earle, Plants of Porto Rico, 6333, on *Sida* sp., Porto Rico.

Asterina Kwangensis P. Henn. in Herb. Berlin on an *Asclepiadaceae*, Kwango, Congo.

Asterina huallagensis P. Henn., Hedwigia 1904, p. 372; Syll. Fung. xvii, p. 879; on *Croton* sp., Peru (non *Asterina huallagensis* [P. Henn.] Theiss. *Lembosia huallagensis* P.H.).

Plate XVI, fig. 34. Slides XXIV, 11, 14; XXXI, 19; XXXIX, 6.

Mostly epiphyllous, effuse; mycelium undulate, reticulate; hyphae brown or pale fuscous, $3.5\text{--}5\ \mu$ thick, forming more or less regular zigzag lines; hyphopodia alternate or unilateral, continuous, sessile, $6\text{--}7\ \mu$ high and $5\text{--}10\ \mu$ broad, lobed, the majority with three flattened or rounded lobes, erect or hooked. Thyriothecia numerous, crowded, flattened-hemispherical, $100\text{--}150\ \mu$ diam., composed of radiating hyphae $3\text{--}3.5\ \mu$ thick, with cells $3\text{--}5\ \mu$ long; dehiscing by a stellate fissure; margin not fimbriate. Asci 8-spored, paraphysate, with a short foot, globose or ovate-pyriform, $27\text{--}35\ \mu$ diam., or $46 \times 22\ \mu$, not stained blue by iodine. Spores conglobate, 2-celled, very slightly constricted, dark brown, $17\text{--}22 \times 8\text{--}10\ \mu$; episporium verrucose, upper cell slightly broader. Pycnidia smaller than the thyriothecia, $70\text{--}85\ \mu$ diam.; conidia continuous, brown, elliptic or pyriform, $18\text{--}23 \times 12\text{--}14\ \mu$.

On leaves of *Sida rhombifolia*, Inanda, 1877, Wood (Wood, 544), 10192.

On leaves of *Sida cordifolia*, Inanda, Wood (Wood, 601), 10194, 9506; Van Staden's Drift, 13/11/17, Doidge, 10858.

On *Hibiscus pedunculatus*, Maritzberg, 21/3/18, Doidge, 9710; East London, 11/11/17, Doidge, 10927.

30. *Asterina tertia* Rac.

On the leaves of different *Acanthaceae* (*Adhatoda*, *Crossandra*, etc.), Buitenzorg, Java, Herb. Raciborsky; Die Gattung *Asterina*, p. 103.

var. *africana* Doidge, var. nov.

Plate XVI, fig. 35. Slides XXVI, 9, 10; XXIV, 12, 15; XXXI, 18; XXXIII, 15.

Epiphyllous; mycelium radiating, consisting of fuscous, undulating hyphae, $3\text{--}3.5\ \mu$ thick, irregularly branched and anastomosing; hyphopodia 1-celled, alternate or unilateral, $6\text{--}7\ \mu$ high and $7\text{--}10\ \mu$ broad, irregularly lobed, the majority either more or less symmetrical, with 2-3 flattened, rounded or bilobulate lobes, or hooked, with 2-4 rounded lobes on the convex side. Thyriothecia crowded, flattened-hemispherical, $120\text{--}130\ \mu$ diam., formed of radiating hyphae about $3\ \mu$ thick, cells about $3.5\ \mu$ long; margin not pronouncedly fimbriate; dehiscence stellate. Asci paraphysate, 8-spored, broadly ovate to spherical, sessile, thickened round the apex, $30\text{--}40 \times 23\text{--}27\ \mu$. Spores conglobate. 1-septate, fuscous, constricted, $15\text{--}18 \times 6.5\text{--}8\ \mu$; upper cell often slightly broader, episporium minutely verrucose at maturity. Pycnidia smaller than the thyriothecia, $50\text{--}70\ \mu$ diam.; conidia brown, continuous, ovate to pyriform, $13\text{--}17 \times 11\text{--}13\ \mu$.

On leaves of *Hypoestes aristata** (sub *A. fimbriata*), Inanda, Wood (Wood, 608), 9512.

On *Hypoestes verticillaris*, Kentani, 6/5/15, Pegler (Pegler, 2317), 9074; van Staden's Drift, 12/11/17, Doidge, 10856.

On *Isoglossa Woodii*, Lemana, Zoutpansberg, 14/8/11, Doidge, 1791; East London, 24/11/17, Doidge, 10923.

On *Dicliptera heterostegia*, Mayville, Durban, 22/7/15, Wood, 9028.

On *Peristrophe* sp., Claridge, Natal, 31/5/15, Doidge, 8998.

Theissen ('Die Gattung *Asterina*,' p. 103) remarks: "Die Art ist kaum mehr als eine Form von *A. diplocarpa*." The species is certainly very closely related to *A. diplocarpa*, but there is a constant if rather slight difference in the form of the hyphopodia. The variety differs from the type in the narrower spores.

SPECIES EXCLUDENDAE.

Asterina capensis Kalch. et Cke., Grevillea, ix, p. 32; Syll. Fung. ii, p. 41 = *Meliola capensis* (K. et Cke.) Th., Ann. Myc. x, 1912, p. 19; Trans. Roy. Soc. of S. Af. v, 1917, p. 731.

Asterina confluens K. et Cke., Grevillea, ix, p. 33; Syll. Fung. i, p. 49, is the conidial stage of some undetermined fungus; Theissen, Die Gattung *Asterina*, p. 4.

Asterina ditricha K. et Cke., Grevillea, ix, p. 32 = *Meliola ditricha* (K. et Cke.) Doidge, Trans. Roy. Soc. of S. Af. v, 1917, p. 728.

Asterina interrupta Wint., Flora, 1884, p. 6; Syll. Fung. ix, p. 381 = *Entopeltis interrupta* (Wint.) v. Höhn., Fragmente z. Myk. 489.

Asterina Macowaniana K. et Cke., Grevillea, ix, p. 33; Syll. Fung. i, p. 41 = *Parenglerula Macowaniana* (K. et Cke.) v. Höhn., l. cit., 525.

Asterina myriadea Cke., Grevillea, x, p. 130; Syll. Fung. ix, p. 389 = *Dimerium myriadeum* (Cke.) Theissen, Ann. Myc. x, p. 193.

Asterina phaeostroma (Cke.), Grevillea, x, p. 130; Syll. Fung. ix, p. 396 = *Balladyna velutina* (Cke.) v. Höhn., Ann. Myc. x, p. 16; Trans. Roy. Soc. of S. Af. v, 1917, p. 716.

Asterina similis Cke., Grevillea, x, p. 130 = *Asterina diplocarpa* Cke., Ann. Myc. x, p. 14.

Asterina solaris K. et Cke., Grevillea, ix, p. 33; Syll. Fung. i, p. 42 = *Asterodothis solaris* (K. et Cke.) Theissen, Ann. Myc. x, p. 179.

Asterina stylospora Cke., Grevillea, x, p. 129, does not belong to the Microthyriaceae, Ann. Myc. x, p. 13.

Asterina toruligena Cke., Grevillea, x, p. 129, is not an *Asterina*, Ann. Myc. x, p. 19.

ASTERINELLA, Th.

Fragmenta brasiliica, v, no. 123; Ann. Myc. x, 1912.

Mycelium superficial, creeping, branching, without hyphopodia. Thyrio-

thecia dimidiate, scutate, inverse, radiate in structure, dehiscing from the centre. Asci globose-ovate or elliptical-cylindrical. Spores brown, 2-celled.

Key to the Species.

- A. Asci apurphysate.
 a. Spores 13–17 μ long.
 i. Hyphae 3–3.5 μ diam. 1. *A. Acokantherae*.
 ii. Hyphae 3.5–5 μ diam., torulose 2. *A. Burchelliae*.
 b. Spores 20–23 μ long 3. *A. Woodiana*.
 B. Asci paraphysate 4. *A. lembozoides*.

1. *Asterinella Acokantherae* Doidge, sp. nov.

Plate XVII, fig. 36. Slides XXIX, 16; XXXI, 13, 14, 17; XLVII, 4, 5.

Hypophyllous, forming thin, black carbonaceous spots up to 5 mm. diam. Mycelium rather scanty; hyphae pale, fuscous, 3–3.5 μ thick, branching irregularly and anastomosing. Thyriothecia very numerous, brown, gregarious, frequently confluent in small groups, flattened-hemispherical 90–115 μ diam., composed of radiating hyphae about 3 μ thick; margin fimbriate. Asci elliptical-cylindrical, sessile, thickened round the apex, apurphysate, 8-spored, 26–35 \times 13–17 μ . Spores distichous or conglobate, fuscous, ellipsoid or sub-clavate, slightly constricted, 13–17 \times 3.5–5 μ . Pycnidia similar to the thyriothecia; conidia hyaline, fusiform, 3-septate, 20–24 \times 3–3.5 μ .

On leaves of *Acokanthera spectabilis*, Durban, Natal, 15/5/97, Wood (Wood, 6450 and 6451), 9510 and 9521.

On *Acokanthera venenata*, Tongaat, Natal, 12/9/13, v. d. Bijl, 6951.

Conidial stage only: on *Cariaca arduina*, Louis Trichardt, Zoutpansberg, 8/4/19, Putterill, 11849.

Medley Wood's specimens are labelled *Dimerosporium Acokantherae*, but the fungus does not correspond with Henning's description (Fung. Africani, p. 4, Engl. Bot. Jahrb., vol. 17).

2. *Asterinella Woodiana* Doidge, sp. nov.

Plate XVII, fig. 38. Slides XXXIV, 9; XL, 4.

Hypophyllous; mycelium thin, effuse, reticulate; hyphae slender, fuscous, 2.5–3 μ thick, tortuous and interwoven, abundantly branched and anastomosing. Thyriothecia fairly numerous, scattered, light brown, 150–160 μ diam., flattened-hemispherical, formed of radiating hyphae 2–3 μ thick, margin crenulate, or irregularly lobed at maturity. Asci ovate to elliptical, 8-spored, apurphysate, 33–37 \times 27–30 μ . Spores conglobate, 2-celled, fuscous, smooth, constricted, 20–23 \times 10 μ , cells sub-equal. Pycnidia similar to the thyriothecia but smaller; conidia (*Asterostomella*) ellipsoid, brown, continuous, 14–16 \times 8–10 μ .

Associated with *Meliola Cryptocaryae*, on leaves of *Cryptocarya Woodii*, Mayville, Natal, 22/7/15, Wood, 9025.

On *Cryptocarya Woodii*, Berea, Durban, 29/1/17, v. d. Bijl, 11362.

3. *Asterinella Burchelliae* Doidge, sp. nov.

Plate XVII, fig. 37. Slides IV, 20; XXXIV, 9; XL, 4.

Epiphyllous, forming minute, black spots about 1 mm. diam. Mycelium poorly developed; hyphae brown, 3.5–5 μ thick, frequently septate, undulating, somewhat torulose, cells 10–13 μ long. Thyriothecia 100–120 μ diam., brown, flattened hemispherical, formed of radiating hyphae about 3 μ thick, margin somewhat fimbriate. Asci ellipsoid to cylindrical, thickly tunicated round the apex, sessile, paraphysate, 27–37 \times 16–20 μ . Spores 13–17 \times 5–6.5 μ , oblong to clavate, rounded at both ends, upper cell shorter.

On leaves of *Burchellia capensis*, Woodville Forest, George, 11/11/17, Doidge, 10940.

Closely related to *Asterina gibbosa*, from which it differs in the poorly developed mycelium and in the absence of regular nodular swellings.

4. *Asterinella lembosioides* Doidge, sp. nov.

Plate XVII, fig. 39. Slides XLIII, 4–6.

Mycelium slender, arachnoid; hyphae fuscous, 1.5–3 μ thick, tortuous, frequently branched and anastomosing. Thyriothecia scattered, hemispherical, 200–240 μ diam., or broadly ellipsoid, 280–320 \times 160–240 μ ; formed of radiating hyphae about 2 μ thick, dehiscing by an irregular central fissure. Asci very numerous, paraphysate, ellipsoid to cylindrical, 33–43 \times 17–20 μ , somewhat thickened round the apex, which is traversed by a terminal pore; paraphyses numerous, hyaline, exceeding the asci, filiform, swollen, club-shaped at the tips. Spores conglobate or sub-distichous, 15–17 \times 8.5–10 μ , 2-celled, fuscous, scarcely constricted cells sub-equal. Pycnidia similar to the thyriothecia; conidia hyaline, continuous, lunate, 17–18 \times 1.5–2 μ .

Parasitic on the mycelium of *Balladyna velutina* and *Meliola amphitricha*, on leaves of *Plectronia Guienzii*, Buccleuch, Natal, 17/7/11, Doidge, 11574.

LEMBOSIA Lev.

Syll. Fung. ii, p. 741; Theissen, *Lembosia-studien*, Ann. Myc. xi (1913).

Mycelium superficial, hyphae branched, septate, with hyphopodia. Thyriothecia dimidiate, inverse, formed of radiating hyphae, typically oblong-linear, dehiscing by an irregular longitudinal fissure. Asci paraphysate, 8-spored. Spores 2-celled, brown.

Key to the Species.

- a. Spores 15-16 μ long 1. *L. natalensis*.
- b. Spores 17-20 μ long.
 - i. Thyriothecia up to 800 μ long 2. *L. congesta*.
 - ii. Thyriothecia not more than 300 μ long 3. *L. radiata*.

1. *Lembosia natalensis* Doidge, sp. nov.

Plate XIX, fig. 44. Slide XXV, 13.

Hypophyllous, effuse; hyphae fuscous, 3-3.5 μ thick, branching and anastomosing; hyphopodia very rare, cylindrical or slightly curved, 6 \times 3 μ . Thyriothecia scattered, elliptic, sometimes forked, 300-500 \times 140-160 μ , dehiscing by a narrow longitudinal slit. Asci paraphysate, 8-spored, ellipsoid to obovate, 30-34 \times 20-24 μ . Spores conglobate, 2-celled, fuscous, ellipsoid, scarcely constricted, 15-16 \times 6-7 μ . Pycnidia flattened-hemispherical, Asterina-like, 200-250 μ diam., composed of radiating hyphae about 2 μ thick, dehiscence stellate; conidia hyaline, fusoid, 18-20 \times 3.5 μ .

On leaves of an undetermined shrub (*Myrtaceae*?), Krantzklouf, Natal, 1/6/15, Doidge, 8984.

2. *Lembosia congesta* Wint.

Exot. Pilze in Flora, 1884, p. 9; Syll. Fung. ix, p. 1105; Hab. ad ramulcos juniores *Carissae arduinae* in Promontorio Bonae Spei, Afr. austr. (MacOwan).

Plate XIX, fig. 45. Slides XXVIII, 11-13, 16.

On the younger branches, or less frequently on the leaves; thyriothecia closely packed, forming black, opaque, round irregular spots up to 4 mm. diam. Thyriothecia black, opaque, elongated linear, straight, curved or flexuous, 500-800 \times 180-220 μ ; oval, attenuated to both ends, 280-340 \times 160-175 μ , or rarely almost hemispherical, 160-190 μ diam; dehiscing by a longitudinal slit. Asci oblong to clavate, attenuated into a short foot, 8-spored, paraphysate 60-70 \times 21-26 μ ; paraphyses filiform, often forked at the apex, tips more or less conglutinate. Spores conglobate or subdistichous, oblong, 1-septate, constricted, fuscous when mature, 17-18 \times 7-9 μ . Mycelium on the leaves well developed, fuscous, undulating, abundantly branched, and anastomosing, with a few sessile, dark brown, hemispherical hyphopodia 6.5-8 \times 6.5 μ , on the primary hyphae. Mycelium on the branches not so well developed; hyphae straighter, more slender, 3.5-5 μ thick, branches parallel, with occasional elongated reticulations.

On *Carissa arduina*, Lemana, Zoutpansberg, 14/8/11, Doidge, 1786; Isipingo, Natal, 21/5/17, Doidge, 10155; Grahamstown, 15/8/17, Gane, 11369; Congo Valley, Oudtshoorn, 9/11/17, Doidge, 10898; Woodville Forest, George, 11/11/17, Doidge, 10929; Howieson's Poort, Grahamstown,

17/11/17, Doidge, 10960; Lovedale, Alice, 18/11/17, Doidge, 10979; Hogg's Back, 15/1/18, J. & M. Henderson, 11345.

On *Carissa acuminata*, Stella Bush, Durban, 7/4/18, Bottomley, 11381.

On *Carissa grandiflora*, Krantzkloof, Natal, 26/5/15, Doidge, 8983; Isipingo, Natal, 27/3/18, Bottomley, 11380.

3. *Lembosia radiata* Doidge, sp. nov.

Plate XIX, fig. 46. Slide XLVI, 8.

Epiphyllous, rarely hypophyllous, forming dense, opaque, black spots 1.5–2.5 mm. diam. Mycelium delicate, radiating; hyphae slender, fuscous, 3–4 μ thick; branches irregular, interwoven and anastomosing; hyphopodia sub-globose, 6–7 μ diam. Primary thyriothecia densely crowded and confluent in the centre of the spot, so that the boundaries of the individual thyriothecia are often indistinguishable; confluent in a stellate manner; secondary thyriothecia often forming a concentric ring, oriented with the long axis on a radius from the centre; 240–300 \times 60–160 μ , formed of radiating hyphae about 3 μ thick; dehiscing by a longitudinal slit almost the length of the thyriothecium. Asci ellipsoid-clavate, 42–45 \times 18–23 μ , 8-spored, somewhat thickened round the apex; paraphyses numerous, hyaline, slender, filiform, slightly exceeding the asci, simple or branched, not swollen at the tips; asci do not stain blue with iodine. Spores sub-distichous, 1-septate, scarcely constricted, fuscous, smooth, 17–20 \times 8–10 μ ; cells sub-equal, but upper locus very slightly broader and rather more broadly rounded.

On leaves of an undetermined shrub (Leguminosae), Rikatli, Portuguese East Africa, 15/9/18, Junod, 11729.

ECHIDNODES Theiss. et Syd.

Ann. Myc. xvii (1915), p. 422.

Like *Lembosia*, but mycelium non-hyphopodiate.

Echidnodes rhoina Doidge, sp. nov.

Plate XVIII, fig. 43. Slides XXVIII, 7–10.

Amphigenous, mostly epiphyllous, forming minute black spots 1–1.5 mm. diam., often very numerous and confluent. Hyphae septate, brown, 2.5–3.5 μ thick, alternately branched, anastomosing; no hyphopodia. Thyriothecia irregularly scattered, occasionally confluent, not very numerous, black, oblong-ellipsoid, straight or curved, or occasionally forked, 300–500 \times 90–150 μ , dehiscing by a longitudinal slit almost the length of the thyriothecium. Asci 8-spored, paraphysate, broadly elliptic-ovate, somewhat thickened at the apex, 35–40 \times 20–24 μ ; paraphyses fairly numerous, filiform, exceeding the asci. Spores distichous or con-

globose, 1-septate, constricted, brown, 13–16 μ long; upper loculus longer and broader, almost globular, 6.5–8 μ broad; lower loculus 5–6.5 μ broad; epispore minutely verrucose at maturity.

On leaves of *Rhus lucida*, Van Staden's Pass, 13/11/17, Doidge, 10887; Howieson's Poort, Grahamstown, 10957.

MORENOELLA Speg.

F. Guaran. i, p. 258; Theissen, Lembosia-studien, Ann. Myc. xi, p. 425.

Mycelium superficial, hyphae branched, septate, with hyphopodia. Thyriothecia dimidiate, inverse, formed of radiating hyphae, typically oblong-linear, dehiscing by an irregular longitudinal fissure, asci paraphysate, 8-spored. Spores 2-celled, brown.

Morenoella Oxyanthæ Doidge, sp. nov.

Slides IV, 17; XXV, 18; XXVI, 17.

Hypophyllous; thyriothecia very densely crowded, forming black or rusty brown opaque spots, which are round-irregular, and up to 5 mm. diam. Thyriothecia elongated, attenuated towards each end, often curved, 400–600 \times 250–300 μ , dehiscing by an irregular, longitudinal slit. Hyphae not distinct in the centre of the spot, but radiating from the thyriothecial mass; these are more or less densely interwoven, pale, fuscous, slender, branched and anastomosing hyphae, 3–3.5 μ thick, with small, globular, alternate hyphopodia. Asci paraphysate, 8-spored, elliptic-ovate, sessile, or very briefly pedicellate, very much thickened round the apex, 23–30 \times 13–16 μ . Spores distichous or conglobate, ellipsoid or sub-clavate, unevenly 1-septate, the upper cell being shorter and broader, slightly constricted, fuscous when mature, 12–16 \times 3.5–5 μ .

On leaves of *Oxyanthus Gerrardi*, Kentani, Pegler (Pegler, 2321), 9073; Town Bush Valley, Maritzberg, 21/3/16, Doidge, 9719.

On *Grumilea capensis*, Woodbush, Zoutpansberg, 7/8/11, Doidge, 1758.

ECHIDNODELLA Theiss. et Syd.

Ann. Myc. xvii (1915), p. 422.

Like *Morenoella*, but mycelium non-hyphopodiate.

Echidnodella Hypolepidis Doidge, sp. nov.

Slides XXVIII, 14, 15.

Epiphyllous, effuse, usually along the midrib of the pinnule, spots small and often confluent. Hyphae septate, pale-fuscous, slender, 2–3 μ thick, tortuous, abundantly branched and anastomosing; no hyphopodia. Thyriothecia gregarious, often confluent, straight or curved, and not infrequently forked, oblong-ellipsoid, 120–240 \times 50–100 μ , dehiscing by a medial, longitudinal slit almost the length of the thyriothecium; composed

of hyphae 3-3.5 μ thick, with cells 3.5-5 μ long. Asci (immature) 8-spored, paraphysate, elliptic-ovate, sessile, rounded at the apex, 20-25 \times 7-10 μ . Mature spores only seen outside the ascus, 1-septate, fuscous, 10-14 \times 3.5-5 μ , upper cell broader and more broadly rounded.

On pinnales of *Hypolepis sparsisora*, Woodville Forest, George, 11/11/17. Doidge, 10930.

AMAZONIA Theiss.

Ann. Myc. ii (1913), 499.

Thyriothecia superficial, dimidiate, scutate, formed of radiating hyphae. Asci paraphysate. Spores 4-septate, brown. Mycelium hyphopodiate.

Amazonia asterinoides (Wint.) Th.

Ann. Myc. ii (1913), 499; and 15 (1917), 421.

Meliola asterinoides Wint., Gaill. Le Genre Meliola, p. 58.

Meliolaster Mackenzii Doidge, Trans. Roy. Soc. of S. Af. viii (1918), p. 122.

Plate XVIII, fig. 42. Slides XLIII, 8-10.

Mostly hypophyllous, less frequently epiphyllous or on the stems, forming minute round spots 1.5-2.5 mm. diam. Mycelium brown, radiating, hyphae flexuous or almost straight, 6-7 μ thick; branches alternate, cells 15-6 μ long; capitate hyphopodia alternate or unilateral, briefly stipitate, curved, 10-15 \times 6-7 μ ; terminal cell sub-globose, convex; mucronate hyphopodia ampulliform, scattered amongst the capitate hyphopodia, neck sometimes sub-uncinate, 12-15 \times 6-7 μ . Thyriothecia gregarious in small groups, flattened-hemispherical or angular by compression, 250-350 μ diam., radiating hyphae straight, 4-6 μ thick, cells about 10 μ long, margin densely fimbriate. Asci paraphysate, evanescent, ellipsoid, 2-spored, 50-57 \times 20-23 μ . Spores cylindrical-compressed or sub-clavate, 4-septate, rounded at both ends, slightly constricted, 33-37 \times 10-13.5 μ .

On *Piper capensis*, Buccleuch, Natal, 17/8/18, Doidge, 11570.

HOST INDEX

(According to Genera and Families).

Abbreviations:—*A.* = *Asterina*; *Ala.* = *Asterinella*; *E.* = *Englerulaster*; *L.* = *Lembosia*; *M.* = *Morenoella*; *Mna.* = *Morenoina*; *Am.* = *Amazonia*; *Mic.* = *Microthyrium*; *S.* = *Seynesia*; *P.* = *Parasterina*; *Ech.* = *Echidnodes*; *Echla.* = *Echidnodella*.

| | | | |
|------------------------------|-----------------------|--------------------------------|----------------------------|
| Acanthaceae | <i>A. fimbriata</i> . | Acokanthera | <i>Ala. Acokantherae</i> . |
| <i>cfr. Dicliptera</i> . | <i>A. tertia</i> var. | Alberta | <i>A. gibbosa</i> var. |
| Hypoestes . | <i>africana</i> . | | <i>megathyria</i> |
| Isoglossa . | | Anacardiaceae | <i>A. Peglerae</i> . |
| Peristrophe . | | <i>cfr. Rhus</i> . | <i>Ech. Rhoina</i> . |
| Sclerochiton . | | Anonaceae | <i>E. Popowiae</i> . |
| Acalypha | <i>A. tenuis</i> . | <i>cfr. Popowia</i> . | |

- Ansellia . . . *A. varipoda*.
 Apocynaceae . . . *P. rigida*.
 cfr. Acokanthera, Ala. Acokantherae.
 Carissa, L. congesta.
 Oncinotis.
 Aquifoliaceae . . . *E. orbicularis*.
 cfr. Ilex, A. Hendersoni.
 Araliaceae . . . *A. ferruginosa*.
 cfr. Cussonia.
 Asclepiadaceae . . . *A. peraffinis*.
 cfr. Tylophora.
 Burchellia . . . *Ala. Burchelliae*.
 Capparidaceae . . . *A. celtidicola* var.
 microspora.
 cfr. Capparis, A. sphaerasca.
 Maerua.
 Capparis . . . *A. sphaerasca.*
 Carissa . . . *Ala. Acokantherae.*
 L. congesta.
 Celastraceae . . . *E. Gymnosporias.*
 cfr. Gymnosporia.
 Putterlickia.
 Chrysophyllum . . . *A. opaca*.
 Claoxylon . . . *A. tenuis*.
 Clausena . . . *A. clausenicola*.
 Combretaceae . . . *A. Combreti*.
 cfr. Combretum.
 Combretum . . . *A. Combreti*.
 Compositae . . . *A. natalensis*.
 cfr. Mikania.
 Cryptocarya . . . *Ala. Woodiana*.
 Cussonia . . . *A. ferruginosa*.
 Dalechampia . . . *A. tenuis*.
 Dicliptera . . . *A. tertia*, var.
 africana.
 Dryopteris . . . *Mna. africana*.
 Ebenaceae . . . *S. orbiculata*.
 cfr. Euclea.
 Euclea . . . *S. orbiculata*.
 Eugenia . . . *A. brachystoma*.
 Euphorbiaceae . . . *A. Excoecariae*.
 cfr. Acalypha, A. tenuis.
 Claoxylon.
 Dalechampia.
 Excoecaria.
 Excoecaria . . . *A. Excoecariae*.
 Flacourtiaceae . . . *A. delicata*.
 cfr. Oncoba, A. celtidicola var.
 Trimeria, microspora.
 Grewia . . . *A. Grewiae*.
- Grumilea . . . *P. brachystoma*
 var. *laza*.
 M. Oxyanthae.
 Gymnosporia . . . *E. Gymnosporias.*
 Hibiscus . . . *A. diplocarpa*.
 Hypoestes . . . *A. fimbriata*.
 A. tertia var.
 africana.
 Hypolepis . . . *Echla. Hypolepidis*.
 Ilex . . . *A. Hendersoni*.
 E. orbicularis.
 Isoglossa . . . *A. tertia* var.
 africana.
 Jasminum . . . *A. erysiphoides*.
 Kraussia . . . *A. gibbosa* var.
 megathyria.
 Lauraceae . . . *Ala. Woodiana*.
 cfr. Cryptocarpa.
 Leguminosae . . . *L. radiata*.
 Loranthaceae . . . *A. loranthicola*.
 cfr. Loranthus.
 Loranthus . . . *A. loranthicola*.
 Maerua . . . *A. celtidicola* var.
 microspora.
 Malvaceae . . . *A. diplocarpa*.
 cfr. Hibiscus.
 Sida.
 Meliaceae . . . *A. Trichiliae*.
 cfr. Trichilia.
 Mikania . . . *A. natalensis*.
 Myrtaceae . . . *P. brachystoma*.
 cfr. Eugenia, L. natalensis.
 Oleaceae . . . *A. erysiphoides*.
 cfr. Jasminum.
 Olinia . . . *A. reticulata*.
 Oliniaceae . . . *A. reticulata*.
 cfr. Olinia.
 Oncinotis . . . *P. rigida*.
 Oncoba . . . *A. celtidicola* var.
 microspora.
 Orchidaceae . . . *A. varipoda*.
 cfr. Ansellia.
 Oxyridicarpus . . . *A. polythyria*.
 Oxyanthus . . . *P. brachystoma*
 var. *laza*.
 M. Oxyanthae.
 Pavetta . . . *A. gibbosa* var.
 megathyria.
 Peristrophe . . . *A. tertia* var.
 africana.

| | | | |
|---------------------------|-----------------------------|-----------------------------|---------------------------|
| Piper | <i>Am. asterinoides</i> . | Kraussia | <i>megathyria</i> . |
| Piperaceae | <i>Am. asterinoides</i> . | Oxyanthus | <i>Ala. Burchelliae</i> . |
| <i>cfr. Piper</i> . | | Pavetta | <i>Ala. lembosoides</i> . |
| Pittosporaceae | <i>A. robusta</i> . | Electronia | <i>M. Oxyanthae</i> . |
| <i>cfr. Pittosporum</i> . | | Randia | |
| Pittosporum | <i>A. robusta</i> . | Tricalysia | |
| Electronia | <i>A. gibbosa</i> var. | Rubus | <i>A. Balansae</i> var. |
| | <i>megathyria</i> . | | <i>africana</i> . |
| | <i>A. fimbriata</i> . | Rutaceae | <i>A. clausenicola</i> . |
| | <i>Ala. lembosoides</i> . | <i>cfr. Clausena</i> . | |
| Polypodiaceae | <i>Echla. Hypolepidis</i> . | Santalaceae | <i>A. polythyria</i> . |
| <i>cfr. Dryopteris</i> . | <i>Mna. africana</i> . | <i>cfr. Osyridicarpus</i> . | |
| Hypolepis | | Sapotaceae | <i>P. implicata</i> . |
| Popowia | <i>E. Popowiae</i> . | <i>cfr. Chryso-</i> | <i>A. opaca</i> . |
| Putterlickia | <i>E. Gymnosporiae</i> . | phyllum | |
| Randia | <i>A. gibbosa</i> var. | Sideroxylon | |
| | <i>megathyria</i> . | Sclerochiton | <i>A. fimbriata</i> . |
| Rhamnaceae | <i>A. rhamnicola</i> . | Sida | <i>A. diplocarpa</i> . |
| <i>cfr. Rhamnus</i> . | <i>A. uncinata</i> . | Sideroxylon | <i>P. implicata</i> . |
| Rhamnus | <i>A. rhamnicola</i> . | Tiliaceae | <i>A. Grewiae</i> . |
| | <i>A. uncinata</i> . | <i>cfr. Grewia</i> . | |
| Rhus | <i>A. Peglerae</i> . | Tricalysia | <i>A. gibbosa</i> var. |
| | <i>Ech. Rhoina</i> . | | <i>megathyria</i> . |
| Rinorea | <i>A. ? vagans</i> . | Trichilia | <i>A. Trichiliae</i> . |
| Rosaceae | <i>A. Balansae</i> var. | Trimeria | <i>A. delicata</i> . |
| <i>cfr. Rubus</i> . | <i>africana</i> . | Tylophora | <i>A. peraffinis</i> . |
| Rubiaceae | <i>A. brachystoma</i> | Viola | <i>A. undulata</i> . |
| <i>cfr. Alberta</i> . | var. <i>laza</i> . | Violaceae | <i>A. vagans</i> . |
| Burchellia | <i>A. fimbriata</i> . | <i>cfr. Rinorea</i> . | <i>A. undulata</i> . |
| Grumilea | <i>A. gibbosa</i> var. | Viola | |

DESCRIPTIONS OF NEW SPECIES, ETC.

Asterina brachystoma (Rehm.) Th.

var. *laza* Doidge, var. nov.

A typo differt mycelio laxo, tenuiore; hyphopodiis minoribus et paucioribus.

Asterina (Clypeolaster) clausenicola Doidge, sp. nov.

Mycelium amphigenum, plerumque epiphyllum; hyphis irregulariter ramosis, undulatis, gracilibus, 3-3.5 μ crassis, fuligineo-brunneis; hyphopodiis alternis, sessilibus, profunde trilobatis vel quinquelobatis, 6-7 μ altis, 9-10 μ latis, a base 3-3.5 μ cr. abrupte attenuatis. Thyriothecia sparsa, hemisphaerica, 110-140 μ diam., ex hyphis angustis 2.5-3 μ crassis contexta, margine fimbriata, stellatim dehiscentia. Asci aparaphysati, octospori, sub-globosi vel ovati, 27-30 \times 23-24 μ . Sporae fuligineo-brunneae, laeves, uniseptatae, leviter constrictae, 19-20 \times 6.5-8 μ , loculo supero parum latiore, utrinque rotundatae.

Hab. in foliis *Clausenae inaequalis*, Hilton Road, Natal, 21/7/18, leg. Doidge, 11606.

Asterina celtidicola P. Henn.

var. *microspora* Doidge, var. nov.

A typo differt sporis minoribus, 14-20 \times 8-10 μ .

Asterina delicata Doidge, sp. nov.

Mycelium epiphyllum, tenuissimum; hyphis alterne ramosis, 3-3.5 μ crassis, fuscis, cellulis 20-24 μ longis; hyphopodiis alternis, sessilibus, aut angularibus, aut sublobatis, 6-7 μ altis, 6-10 μ latis. Thyriothecia gregaria vel sparsa, applanato-hemisphaerica, 100-130 μ diam., ex hyphis rectis 3 μ crassis contexta, centro irregulariter aperta. Asci aparaphysati, ovati vel sub-globosi, 26-33 \times 33-40 μ . Sporae brunneae, 1-septatae, constrictae, 20-22 \times 10-12 μ , laeves, utrinque rotundatae, loculis fere aequalibus.

Hab. in foliis *Trimeriae alnifoliae*, prope Durban, Natal, 22/7/15, leg. Medley Wood, 9062.

Asterina erysiphoides Kalch. et Cke. Char. emend.

Mycelium effusum, epiphyllum, tenue; hyphis brunneis, 3.5-5 μ crassis, ramosis, anastomosantibusque; hyphopodiis alternis, sessilibus, continuis, erectis v. uncinatis, irregulariter 3-5 lobatis, 7-13 μ altis, 5-10 μ latis. Thyriothecia applanato-hemisphaerica, sub-opaca, fimbriata, 120-130 μ diam., ex hyphis 3-3.5 μ crassis contexta, stellatim dehiscentia. Asci aparaphysati, sub-globosi, 30-34 μ diam. Sporae brunneae, a maturitate verrucosae, 1-septatae, constrictae, utrinque rotundatae, 20-23 \times 10-12 μ , loculo superiore latiore.

Hab. in foliis *Jasmini multipartiti*, Natal, 14/7/15, leg. Medley Wood, 9018.

Asterina Excoecariae Doidge, sp. nov.

Mycelium amphigenum, effusum, hyphis tenuibus, undulatis, 3-3.5 μ crassis, alterne ramosis, cellulis circ. 16 μ longis; hyphopodiis sessilibus, alternis vel unilateralibus, varie lobatis, 6-7 μ altis, 6-8 μ latis. Thyriothecia sparsa, applanato-hemisphaerica, 100-120 μ diam., ex hyphis angustis, 2.5-3 μ cr. contexta, stellatim dehiscentia. Asci aparaphysati, octospori, sub-globosi, 35-40 μ diam. Sporae brunneae, uniseptatae, constrictae, 23-27 \times 12-13.5 μ ; episporio a maturitate verrucoso; loculo superiore latiore.

Hab. in foliis *Excoecariae* sp., Winkle Spruit, Natal, leg. Doidge, 9009.

Asterina ferruginosa Doidge, sp. nov.

Mycelium epiphyllum; hyphis brunneis, tenuibus, 4-6 μ crassis, alterne ramosis, cellulis 23-27 μ longis; hyphopodiis continuis, alterne vel unilateralibus, hemisphaericis vel sub-globosis, 6-8 μ altis, 8-10 μ latis, rare stipitatis, 12-13 μ altis. Thyriothecia numerosa, sparsa vel gregaria,

applanato-hemisphaerica, ferruginea, 160–190 μ diam., ex hyphis rectis, 3–3.5 μ cr. contexta, margine copiose fimbriato, stellatim dehiscencia. Asci aparaphysati, octospori sub-globosi, 33–37 μ diam. Sporae brunneae, leniter constrictae, laeves, 23–26 \times 11–12.5 μ , loculo superiore parum latiore.

Hab. in foliis *Cussoniae umbelliferae*, Woodbush, 3/8/11, leg. Doidge, 1774.

Asterina gibbosa Gaill.

var. *megathyria* Doidge, var. nov.

A typo differt thyriotheceis gregariis, majoribus, 140–200 μ diam. ex hyphis 2–4 μ cr., rectis, contextis; ascis 33–34 \times 27–33 μ .

Asterina Hendersoni Doidge, sp. nov.

Mycelium amphigenum, undulatum; hyphis brunneis, flexuosis, 5–6 μ crassis, sub-torulosis, alterne ramosis, cellulis 6–8 μ longis; hyphopodiis alternis, hemisphaericis v. sub-angulatis, 3.5–6 μ diam. Thyriothece sparsa, applanato-hemisphaerica, 150–200 μ diam., ex hyphis brunneis, undulatis, 3.5 μ crassis contexta, irregulariter dehiscencia. Asci aparaphysati, octospori, ovati, 45–50 \times 26–33 μ . Sporae laeves, brunneae, 23–25 μ longae, constrictae, loculo supero sub-globoso, 13–13.5 μ lato, infero 10–11 μ lato.

Hab. in foliis *Ilicis capensis*, Hogg's Back, 15/1/18, leg. J. et M. Henderson, 11341, 11342.

Parasterina implicata Doidge, sp. nov.

Mycelium epiphyllum, implicatum; hyphis brunneis, torulosis, 6–7 μ crassis, irregulariter ramosis, reticulatis, cellulis 15–25 μ long.; hyphopodiis sessilibus, alternis, paucis, hemisphaericis, ovatis vel oblique compressis, 6–10 μ altis, 10–6 μ latis. Thyriothece gregaria, applanato-hemisphaerica, 300–400 μ diam., ex hyphis 3.5–5 μ crassis contexta, irregulariter v. stellatim dehiscencia. Asci ovati v. globosi, octospori, paraphysati, 57–73 \times 50–70 μ ; paraphysibus numerosis, filiformis. Sporae fuscae, uniseptatae, constrictae, 35–40 \times 10–13 μ , loculo supero parum latiore.

Hab. in foliis *Sideroxylon inermis*, East London, 24/11/17, leg. Doidge, 10922.

Asterina natalensis Doidge, sp. nov.

Mycelium epiphyllum, tenue; hyphis brunneis, 3–5 μ crassis, irregulariter ramosis; hyphopodiis plerumque alternis, rare oppositis; breviter pedicellatis, 8–14 μ altis, 6–10 μ latis, supra sublobatis vel curvatis. Thyriothece applanato-hemisphaerica, 120–130 μ diam., ex hyphis 3–3.5 μ cr. contexta, margine fimbriata, stellatim dehiscencia. Asci aparaphysati, lati cylindranei v. globosi, octospori 26–32 \times 20–24 μ . Sporae brunneae, uniseptatae, constrictae, 15–19 \times 9–10 μ , loculo supero parum latiore, episporio tenuiter verrucoso.

Hab. in foliis *Mikaniae* sp., Winkle Spruit, Natal, 28/5/15, leg. Doidge, 9001.

Asterina Peglerae Doidge, sp. nov.

Mycelium hypophyllum; hyphis fuscis, tenuibus, 3.5–4 μ crassis, alterne ramosis; hyphopodiis alternis, pedicellatis, 10–15 μ altis, 6–10 μ latis, supra bi- v. trilobatis, rectis vel recurvatis. Thyriothecia sparsa, ex hyphis undulatis, 2.5–3 μ cr. contexta; stellatim dehiscentia; ambitu fimbriata. Asci aparaphysati, sub-globosi, octospori, 45–50 \times 43–45 μ . Sporae atro-brunneae, opacae, uniseptatae, constrictae, 23–28 \times 13–16.5 μ , loculo supero majore, episporio ciliata.

Hab. in foliis *Rhois*? sp., Kentani, 16/9/15, leg. Pegler (Pegler, 2354), 9130.

Asterina polythyria Doidge, sp. nov.

Mycelium epiphyllum; hyphis brunneis, sinuosis, 3.5–6.5 μ crassis, cellulis 10–20 μ longis, ramis plerumque oppositis; hyphopodiis continuis, 2–3 lobatis, 5–7 μ altis, 6–10 μ latis. Thyriothecia numerosa, densiuscule disposita, aut applanato-hemisphaerica, 150–170 μ diam., stellatim dehiscentia, aut oblonga, 190–200 \times 140 μ , rima longitudine dehiscentia. Asci cylindracei v. ovati, aparaphysati, octospori, 26–40 \times 20–24 μ . Sporae brunneae, sub-constrictae, laeves, 16–20 \times 6–7 μ , loculo supero paulo majore.

Hab. in foliis *Osyridicarpa natalensis*, Tongaat, Natal, 12/9/13, leg. v. d. Bijl, 6949.

Asterina raripoda Doidge, sp. nov.

Mycelium epiphyllum, parce evolutum, alterne ramosum; hyphis fuscis 3.5–5 μ crassis, undulatis, cellulis 10–15 μ longis; hyphopodis raris, alternis, continuis, hemisphaericis, 4–5 μ altis, 6–7 μ latis. Thyriothecia sparsa, applanato-hemisphaerica, alia in summis hyphis secundariis, alia in mediis hyphis primariis oriunda, 150–200 μ diam., centro umbilicato et irregulariter stellatim dehiscentia, margine crenulata. Asci aparaphysati, cylindracei v. ovati, octospori, 40–52 \times 16–24 μ . Sporae brunneae, vix constrictae, laeves, 15–18 \times 7–10 μ , loculo supero latiore, globose; infere ellipsoideo.

Hab. in foliis *Anselliae africanae*, Zululand, April 1913, leg. M. Franks, 6687.

Asterina reticulata K. et Cke., char. emend.

Mycelium amphigenum, effusum, reticulatum; hyphis brunneis, rectis, 5–6 μ crassis, cellulis 15–30 μ longis; ramis plerumque oppositis, anastomosantibus; hyphopodiis alternis, breviter pedicellatis, clavatis, recurvatis v. sub-lobatis, 7–13 \times 6–8 μ . Thyriothecia applanato-hemisphaerica, 160–240 μ diam., ex hyphis rectis, 3–3.5 μ cr. contexta, margine fimbriato, poro irregulari centrali et demum stellatim dehiscentia. Asci aparaphysati, sessiles, ovati, 45–50 \times 30–33 μ . Sporae brunneae, uniseptatae, constrictae, laeves, 20–23 \times 10 μ , loculis sub-aequalibus, vel supero parum latiore.

Hab. in foliis *Oliniae* sp., Barberton, 18/1/91, leg. Galpin (Galpin, 1275).

Asterina rhamnicola Doidge, sp. nov.

Mycelium epiphyllum, tenue; hyphis rectis, brunneis, 6-7 μ crassis, alterne ramosis, cellulis 25-30 μ long.; hyphopodiis alternis, continuis, cylindraceutis v. hemisphaericis, 6-10 μ altis, 6-7 μ latis. Thyriothecia pauca, sparsa, conico-hemisphaerica, quam mycelium pallidiores, 225-280 μ diam., ex hyphis rectis, 3-5 μ cr. contexta, margine haud fimbriata, medio irregulariter dehiscentia. Asci paraphysati, late ellipsoidei vel ovati, octospori, 45-50 \times 23-33 μ . Sporae fuscae, obsolete constrictae, laeves, 23-25 \times 9-10 μ , loculo supero majore.

Hab. in foliis *Rhamni prinoides*, Woodbush, Transvaal, 4/8/11, leg. Doidge, 1752.

Parasterina rigida Doidge, sp. nov.

Mycelium epiphyllum, hyphis brunneis, 5-6 μ crassis, alterne ramosis, anastomosantibus, cellulis 16-20 μ long.; hyphopodiis numerosis, plerumque oppositis, continuis, hemisphaericis vel ovatis, 6-8 μ altis, 5-6 μ latis. Thyriothecia congregata, applanato-hemisphaerica, 250-400 μ diam., ex hyphis rectis, 5 μ crassis contexta, medio irregulariter dehiscentia. Asci paraphysati, late ellipsoidei vel ovati, 60-75 \times 30-40 μ , tunicati, apice poro pertusi; paraphysibus filiformis, apicibus incrassatis. Sporae fuscae, uniseptatae, constrictae, laeves, 27-33 \times 13-15 μ , loculo supero majore.

Hab. in foliis *Oncinotis inandensis*, Buccleuch, Natal, 11/5/16, leg. Doidge, 9722.

Asterina robusta Doidge, sp. nov.

Mycelium epiphyllum, atro-brunneum; hyphis torulosis, 6-7 μ cr., cellulis circ. 20 μ long., alterne vel oppositè ramosis; hyphopodiis unilateralibus vel alternis, continuis, sub-hemisphaericis, 6-6.5 \times 6.5-7 μ . Thyriothecia applanato-hemisphaerica, opaca, atro-brunnea, ex hyphis rectis circ. 5 μ cr. contexta, medio irregulariter dehiscentia. Asci paraphysati, octospori, 65-75 \times 45-55 μ , mucos viridulo involuti. Sporae atro-brunneae, uniseptatae, constrictae, 35-40 \times 18-20 μ , loculis globosis, supero parum latiore.

Hab. in foliis *Pittospori viridiflori*, Mossel Bay, 22/7/15, leg. Pole Evans, 9066.

Asterina tertia Rac.

var. *africana* Doidge, var. nov.

A typo differt sporis angustioribus; sporis 15-18 \times 6.5-8 μ . Hab. in foliis *Isoglossae Woodii*, Zoutpansberg, 14/8/11, leg. Doidge, 1791.

Asterina Trichiliae Doidge, sp. nov.

Mycelium epiphyllum; hyphis brunneis, rectis, 4-6 μ crassis, oppositè ramosis; hyphopodiis oppositis, rare alternis, cylindraceutis v. pyriformis, continuis, 6-10 μ altis, 4-5 μ latis. Thyriothecia sparsa, applanato-hemisphaerica, opaca, ex hyphis rectis, 3-3.5 μ crassis contexta, margine fimbriata,

stellatim dehiscentia. Asci aparaphysati, octospori, ovati vel sub-globosi, $40-46 \times 43-50 \mu$, mucro viridulo involuti. Sporae atro-brunneae, uniseptatae, constrictae, $25-27 \times 12-13 \mu$, episporio verrucoso, loculo supero parum latiore.

Hab. in foliis *Trichiliae Dregeanae*, Winkle Spruit, Natal, 28/5/16, leg. Doidge, 9006.

Asterina uncinata Doidge, sp. nov.

Mycelium epiphyllum, effusum, tenue, irregulariter ramosum; hyphis undulatis, $5-6 \mu$ crassis, cellulis $26-33 \mu$ long.; hyphopodiis alternis, uncinatis, rare oppositis, pedicellatis, $20-40 \mu$ altis; cellula basali, 1-2 septata, $7-30 \mu$ longa, cylindrica, recta, curvata vel abrupte geniculata; cellula superiore clavata, v. cylindrica, recta vel uncinata, rare sub-lobata. Thyriothecia applanato-hemisphaerica, $200-280 \mu$ diam., ex hyphis medio rectis, margine undulatis, $3-5 \mu$ crassis contexta; poro centrali et stellatim dehiscentia, margine haud fimbriata. Asci aparaphysati, sub-globosi, $42-50 \times 40-45 \mu$. Sporae atro-brunneae, opacae, $30-40 \times 16-20 \mu$, uniseptatae, valde constrictae; loculis ovatis, supero $18-20 \mu$ lato, infero $14-16 \mu$ lato.

Hab. in foliis *Rhamni prinoides*, Brander's High Forest, Victoria East, 12/8/15, leg. v. d. Bijl, 9463. *A. rhamnicola* consocia.

Asterina undulata Doidge, sp. nov.

Mycelium epiphyllum, laxum, tenue; hyphis pallide fuscis, undulatis, gracilibus, $5-6 \mu$ crassis, laxe ramosis, cellulis $18-20 \mu$ long., hyphopodiis alternis, continuis $5-6.5 \mu$ altis, $7-10 \mu$ latis, varie lobatis. Thyriothecia applanato-hemisphaerica, in summis hyphis secundariis oriunda, congregata, margine haud fimbriata, ex hyphis angustis, rectis, $2.5-3 \mu$ cr. contexta, stellatim dehiscentia. Asci aparaphysati, octospori, ovati, $20-24 \times 17-20 \mu$. Sporae brunneae, anguste ovatae, uniseptatae, constrictae, $13-15 \times 6-8.5 \mu$, loculo supero parum latiore.

Hab. in foliis *Violae abyssinicae*, Woodbush, Zoutpansberg, 4/8/11, leg. Doidge, 1769.

Asterinella Acokantherae Doidge, sp. nov.

Mycelium parvum, epiphyllum; hyphis pallide fuscis, $3-3.5 \mu$ diam., irregulariter ramosis. Thyriothecia congregata, applanato-hemisphaerica, $90-115 \mu$ diam., ex hyphis rectis, 3μ cr. contexta, margine fimbriata. Asci ellipsoidei v. cylindracei, sessiles, apice tunicati, aparaphysati, octospori, $26-35 \times 13-17 \mu$. Sporae fuscae, distichae vel conglobatae, ellipticae v. sub-clavatae, uniseptatae, obsolete constrictae, $13-17 \times 3.5-5 \mu$.

Hab. in foliis *Acokantherae venenatae*, Tongaat, Natal, 12/9/13, leg. v. d. Bijl, 6951.

Asterinella Burchelliae Doidge, sp. nov.

Mycelium epiphyllum, parce evolutum; hyphis brunneis, sub-torulosis

3.5–5 μ crassis, cellulis 10–13 μ longis, undulatis. Thyriothechia applanato-hemisphaerica, 100–120 μ diam., ex hyphis rectis, 3 μ cr. contexta, margine sub-fimbriata. Asci aparaphysati, elliptici v. cylindracei, apice crasse tunicati, 27–37 \times 16–20 μ . Sporae oblongae v. clavatae, 13–17 \times 5–6.5 μ , utrinque rotundatae, loculo supero brevior.

Hab. in foliis *Burchelliae capensis*, Woodville Forest, George, 11/11/17, leg. Doidge, 10940.

Asterinella lembosioides Doidge, sp. nov.

Mycelium tenue, arachnoideum; hyphis fuscis, tortuosis, 1.5–3 μ crassis, dense ramosis, anastomosantibus. Thyriothechia sparsa; hemisphaerica, 200–240 μ diam., vel late elliptica, lembosioides, 280–320 \times 160–240 μ ; ex hyphis rectis circ. 2 μ cr. contexta, medio irregulariter dehiscentia. Asci numerosi, paraphysati, elliptici v. cylindracei, 33–43 \times 17–20 μ , apice incrassati et poro pertusi; paraphysibus numerosis, hyalinis, ascos superantibus, apice leniter incrassatis. Sporae conglobatae v. sub-distichae, 15–17 \times 8.5–10 μ , uniseptatae, obsolete constrictae, loculis sub-aequalibus.

Parasitica in mycelio *Balladynae velutinae* et *Meliolae amphitrichae* in foliis *Plectroniae Guienzii*, Buccleuch, Natal, 17/7/18, leg. Doidge, 11574.

Asterinellae Woodiana Doidge, sp. nov.

Mycelium hypophyllum, effusum, tenue, reticulatum; hyphis tenuibus, fuscis, 2.5–3 μ crassis, tortuosis et intertextis, valde ramosis, anastomosantibus. Thyriothechia sparsa, brunnea, ex hyphis rectis, 2–3 μ cr. contexta, margin crenulato v. a maturitate irregulariter lobato. Asci ovati v. elliptici, octospori, aparaphysati, 33–37 \times 27–30 μ . Sporae conglobatae, fuscae, laeves, uniseptatae, constrictae, 20–23 \times 10 μ , loculis sub-aequalibus.

Meliola Cryptocarya consocia, in foliis *Cryptocaryae Woodii*, Mayville, Natal, 22/7/15, leg. Medley Wood, 9025.

Englerulaster Popowiae Doidge, sp. nov.

Mycelium epiphyllum, brunneum, radiatum; hyphis 5–6 μ crassis, crebre septatis, ramis oppositis v. alternis, anastomosantibus; hyphopodiis sessilibus, alternis, nonnunquam oppositis, capitatis v. ellipsoideis, rectis v. recurvatis, 10–13.5 \times 6–8 μ , rare 16 μ altis. Thyriothechia atro-brunnea, 160–190 μ diam., ex hyphis 5–6 μ cr. contexta, ex centro demum latius aperta, margine fimbriata. Asci globosi v. ovati, apedicellati, octospori, aparaphysati, 40–47 \times 30–40 μ . Sporae brunneae, constrictae, uniseptatae, 21–27 \times 10–13.5 μ , loculis sub-globosis, aequalibus, v. supero parum latiore; episporio minute verrucoso.

Hab. in foliis *Popowiae caffrae*, Buccleuch, Natal, 24/3/16, leg. Doidge, 9714.

Lembosia natalensis Doidge, sp. nov.

Mycelium hypophyllum, effusum; hyphis fuscis, 3–3.5 μ crassis, ramosis-anastomosantibus; hyphopodiis paucis, cylindraceis v. subcurvatis, 6 \times 3 μ .

Thyriothecia sparsa, elliptica, nonnunquam bifurcata, $300-500 \times 140-160 \mu$, rima anguste longitudinale dehiscencia. Asci paraphysati, octospori, ellipsoidei v. obovati, $30-34 \times 20-24 \mu$. Sporae conglobatae, fuscae, uniseptatae, ellipsoideae, obsolete constrictae, $15-16 \times 6-7 \mu$. Pyrenidia applanato-hemisphaerica. Asterinoidea, $200-250 \mu$ diam., ex hyphis circ. 2μ cr. contexta, stellatim dehiscencia. Conidia hyalina, fuscoidea, $18-20 \times 3.5 \mu$.

Hab. in foliis fruticis ignotis (? *Myrtacearum*), Krantzklouf, Natal, 1/6/15, leg. Doidge, 8984.

Lembosia radiata Doidge, sp. nov.

Mycelium epiphyllum rare hypophyllum, plagulas opacas $1.5-2.5$ mm. diam., efficiens; hyphis tenuibus fuscis, $3-5 \mu$ crassis, ramis intertextis, anastomosantibus; hyphopodiis sub-globosis, $6-7 \mu$ diam. Thyriothecia primaria centro stellatim congregata, secundaria in circulo concentrico radiatim disposita; ellipsoidea, $240-300 \times 60-160 \mu$, ex hyphis circ. 3μ cr. contexta, rima longitudinale dehiscencia. Asci paraphysati, octospori, ellipsoidei v. clavati, $42-45 \times 18-23 \mu$; paraphysibus tenuibus, filiformis, vix ascos superantibus, simplicibus v. bifurcis, apice haud incrassatis. Sporae sub-distichae, uniseptatae, obsolete constrictae, fuscae, laeves, $17-20 \times 8-10 \mu$, loculis subaequalibus vel supero parum latiore.

Hab. in foliis *Leguminosae* indet., Rikatli, Portuguese East Africa, Sept., 1918, leg. Junod, 11729.

Echidnodes rhoia Doidge, sp. nov.

Mycelium amphigenum, plerumque epiphyllum; hyphis septatis, brunneis, $2.5-3.5 \mu$ crassis, alterne ramosis; hyphopodiis nullis. Thyriothecia sparsa, haud numerosa, atra, oblonga vel ellipsoidea, recta v. curvata, rare bifurca, $300-500 \times 90-150 \mu$, rima longitudinale dehiscencia. Asci paraphysati, octospori, late ellipsoidei v. ovati, apice obsolete incrassati, $35-40 \times 20-24 \mu$; paraphysibus filiformis, ascos superantibus. Sporae distichae v. conglobatae, brunneae, uniseptatae constrictae, $13-16 \mu$ longae; episporio minute verrucoso.

Hab. in foliis *Rhois lucidae*, van Staden's Pass, 13/11/17, leg. Doidge, 10887.

Microthyrium maculicolum Doidge, sp. nov.

Thyriothecia epiphylla in maculas fuscas sparsa, atro-brunnea, applanato-hemisphaerica, $150-190 \mu$ diam., ex hyphis fuscis $3-4 \mu$ crassis contexta, margine haud fimbriata. Asci octospori, paraphysati elliptici, apice late rotundati, $70 \times 27 \mu$ vel ovati, $50-57 \times 30-43 \mu$, apedicellati, tenuiter tunicati. Sporae conglobatae v. sub-parallelae, hyalinae, 1-septatae, haud v. obsolete constrictae, $21-23.5 \times 6.5-10 \mu$, loculo supero latiore.

Hab. in foliis fruticis indet. (*Capparis*?), Durban, 11/4/18, leg. Bottomley, 11668.

Echidnodella Hypolepidis Doidge, sp. nov.

Epiphyllum, effusum; hyphis fuscis, pallidioribus, tenuibus, 2-3 μ crassis, tortuosis, dense ramosis, anastomosantibus; hyphopodiis nullis. Thyriothecia congregata, recta v. curvata, nonnunquam bifurca, oblonga v. elliptica, 120-240 \times 50-100 μ , rima longitudinale dehiscencia, ex hyphis 3-3.5 μ cr. contexta. Asci (immaturi) octospori, paraphysati, elliptici vel ovati, apice rotundati, 20-25 \times 7-10 μ . Sporae (maturae ex ascis visae) fuscae, haud v. obsolete constrictae, 10-14 \times 3.5-4 μ , loculo supero latiore.

Hab. in pinnulis *Hypolepidis sparsisorae*, George, 11/11/17, leg. Doidge, 10930.

Morenoella Oxyanthae Doidge, sp. nov.

Hypophylla; thyriothecia crustose denseque congregata, elongata, utrinque attenuata, saepe curvata, 400-600 \times 250-300 μ , rima longitudinale irregulare dehiscencia. Mycelium radiatum, hyphis tenuibus, intertextis, ramosis, anastomosantibus, 3-3.5 μ cr., hyphopodiis minutis, alternis, globosis. Asci paraphysati, octospori, elliptici vel ovati, sessiles v. breviter pedicellati, apice valde incrassati. Sporae distichae v. conglobatae, ellipticae v. subclavatae, vix constrictae, uniseptatae, fuscae, 12-16 \times 3.5-5 μ , loculo supero brevior et latior.

Hab. in foliis *Oxyanthi Gerrardi*, Kentani, leg. Pegler (Pegler, 2321), 9073.

Morenoina africana Doidge, sp. nov.

Epiphyllum, mycelium evanescens. Thyriothecia sparsa, anguste elliptica, 120-400 \times 65-100 μ , recta v. subcurvata, nonnunquam bifurca v. aliquantum sinuosa, rima longitudinale dehiscencia, ex hyphis 2.5-3 μ crassis contexta, margine breviter fimbriata. Asci (immaturi) paraphysati, ellipsoidei v. clavati, breviter pedicellati, 23-27 \times 10-12 μ , jodo non caeruleascentes. Sporae (extra ascos visae), fuscae, obsolete constrictae, laeves, 12-14 \times 5-6.5 μ , loculis aequalibus.

Hab. in pinnulis *Dryopteridis inaequalis*, Zwartkop, Natal, 19/7/18, leg. Doidge, 11605.

EXPLANATION OF PLATES XIII-XIX.

[All drawings were made with the camera lucida, and with the same magnification (Zeiss obj. D, No. 5 ocular).]

FIG.

1. *Englerulaster Popoviae* Doidge, n. sp. (a) Mycelium showing hyphopodia; (b) spores.
2. *Englerulaster orbicularis* (B. & C.) v. Höhn. (a) Mycelium showing hyphopodia and incipient thyriothecium; (b) immature and (c) mature spores; (d) conidia.
3. *Parasterina implicata* Doidge, n. sp. (a) Mycelium; (b) spores.
4. *Parasterina brachystoma* (Rehm.) Th. (a) Mycelium; (b) spores.
5. *Parasterina rigida* Doidge, n. sp. (a) Mycelium; (b) spores.
6. *Asterina gibbosa* Gaill. var. *megathyria*, n. var. (a) Mycelium with "node cells"; (b) ascus; (c) spores.

7. *Asterina natalensis* Doidge, n. sp. (a) Mycelium; (b) spores; (c) conidia.
8. *Asterina Combreti* Syd. (a) Mycelium and pycnidium; (b) immature and (c) mature spores; (d) conidia.
9. *Asterina Peglerae* Doidge, n. sp. (a) Mycelium; (b) spores.
10. *Asterina tenuis* Wint. (a) Mycelium; (b) spores; (c) conidia.
11. *Asterina fimbriata* Kalch. & Cke. (a) Mycelium; (b) spores.
12. *Asterina reticulata* Kalch. & Cke. (a) Mycelium; (b) spores; (c) conidia.
13. *Asterina uncinata* Doidge, n. sp. (a) Mycelium showing two- and three-celled hyphopodia; (b) spores.
14. *Asterina delicata* Doidge, n. sp. (a) Mycelium; (b) spores; (c) conidia.
15. *Asterina Grewiae* Cke. (a) Mycelium; (b) spores; (c) conidia.
16. *Asterina Trichiliae* Doidge, n. sp. (a) Mycelium; (b) spores.
17. *Asterina varipoda* Doidge, n. sp. (a) Mycelium; (b) spores.
18. *Asterina ferruginosa* Doidge, n. sp. (a) Mycelium; (b) spores.
19. *Asterina rhamnicola* Doidge, n. sp. (a) Mycelium; (b) spores.
20. *Asterina Hendersoni* Doidge, n. sp. (a) Mycelium; (b) spores; (c) conidia.
21. *Asterina opaca* Syd. (a) Mycelium; (b) spores.
22. *Asterina robusta* Doidge, n. sp. (a) Mycelium; (b) spores; (c) conidia.
23. *Asterina erysiphoides* Kalch. & Cke. (a) Mycelium; (b) spores; (c) conidia.
24. *Asterina Balansae* (Speg.) Th., var. *africana* Sacc. (a) Mycelium; (b) spores; (c) conidia.
25. *Asterina Ezcoerariae* Doidge, n. sp. (a) Mycelium; (b) spores; (c) conidia.
26. *Asterina undulata* Doidge, n. sp. (a) Mycelium, showing hyphopodia and two incipient thyriothecia; (b) mature and (c) immature spores.
27. *Asterina polythyria* Doidge, n. sp. (a) Mycelium; (b) spores; (c) conidia.
28. *Asterina peraffinis* Speg. (a) Mycelium; (b) spores.
29. *Asterina celtidicola* P. Henn., var. *microspora* var. nov. (a) Mycelium; (b) spores; (c) conidia.
30. *Asterina* ? *vagans* Speg. (a) Mycelium; (b) spores.
31. *Asterina sphaerascas* Thüm. (a) Mycelium; (b) spores; (c) conidia.
32. *Asterina loranthicola* Syd. (a) Mycelium; (b) spores; (c) conidia.
33. *Asterina clausenicola* Doidge, n. sp. (a) Mycelium; (b) spores; (c) conidia.
34. *Asterina diplocarpa* Cke. (a) Mycelium; (b) spores; (c) conidia.
35. *Asterina tertia* Rac., var. *africana* n. var. (a) Mycelium; (b) spores; (c) conidia.
36. *Asterinella Acokantherae* Doidge, n. sp.
37. *Asterinella Burchelliae* Doidge, n. sp.
38. *Asterinella Woodiana* Doidge, n. sp.
39. *Asterinella lembosoides* Doidge, n. sp. The finer mycelium of the *Asterinella* can be seen investing the stouter hyphae of *Balladyna velutina*.
40. *Microthyrium maculicolum* Doidge, n. sp.
41. *Morenoina africana* Doidge, n. sp. Shows the elongated thyriothecia and the orbicular pycnidia.
42. *Amazonia asterinoides* Th.
43. *Echidnodes rhoina* Doidge, n. sp.
44. *Lembosia natalensis* Doidge, n. sp. Showing elongated thyriothecia and a round pycnidium.
45. *Lembosia congesta* Wint.; from the leaf of *Carissa* sp. On the stem the mycelium is not so well developed, and the hyphae are inclined to run parallel, following the striations in the bark.
46. *Lembosia radiata* Doidge, n. sp. Showing the orientation of the thyriothecia.





10



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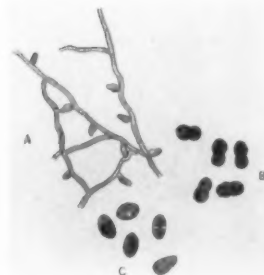
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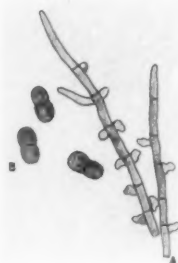
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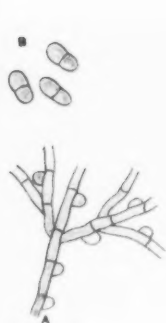
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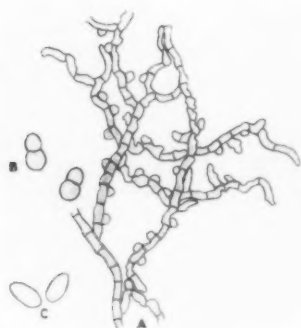
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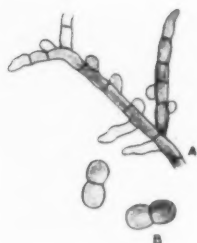
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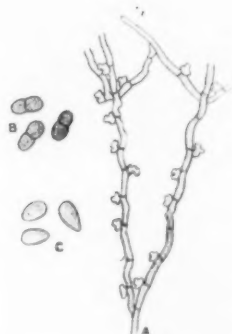
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21



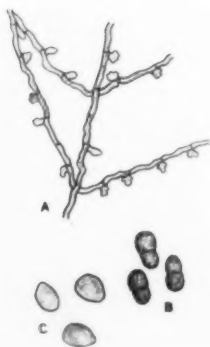
22



23



24



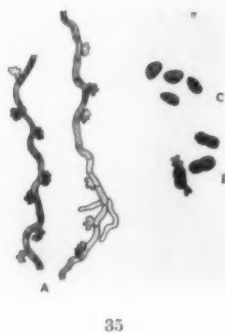
25

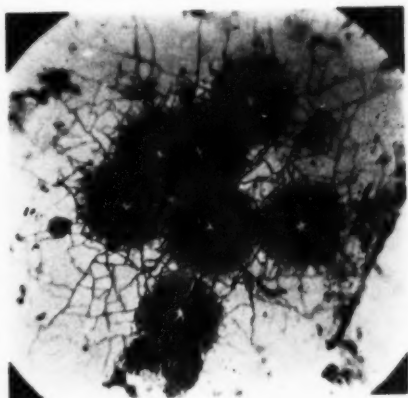


26

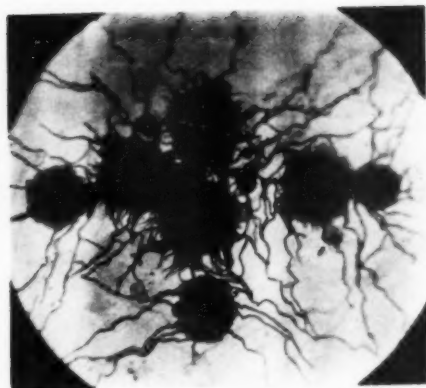


27





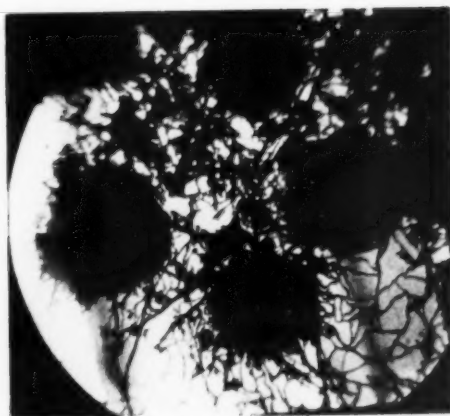
36



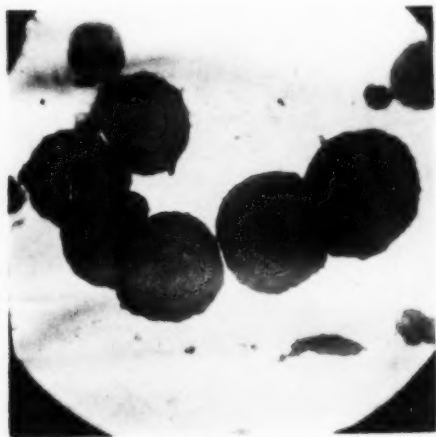
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38



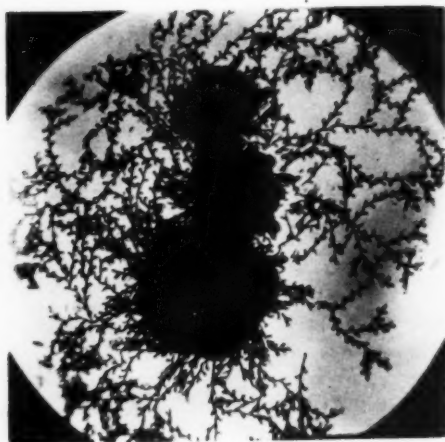
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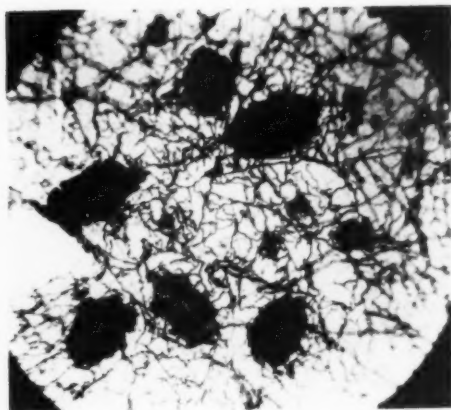
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41



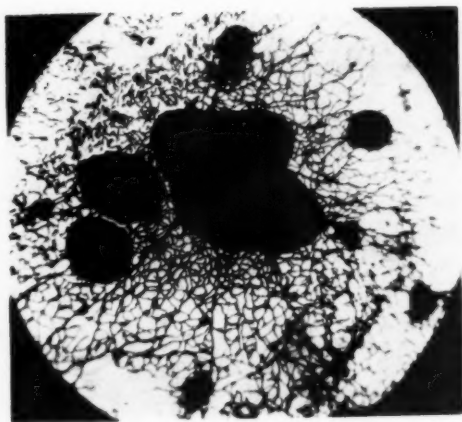
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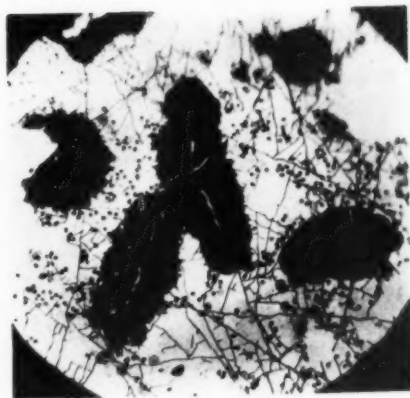
43



46



45



44

AN INVESTIGATION OF EVAPORATION OVER FREE
SURFACES OF WATER IN INLAND
SOUTH AFRICA.

By A. H. WALLIS, C.E.

Having constructed several dams, of capacities varying from 5 millions to 45 million gallons, in the Bechuanaland Protectorate, and noticing the great losses which occurred through evaporation, the author has gone into this question with a view to ascertaining whether some simple method cannot be arrived at to guide the engineer in making provision for such losses.

Through the courtesy of Mr. Innes, the Union Astronomer, Father Goetz of Bulawayo, and Dr. Sutton of Kimberley, the author was afforded an opportunity of inspecting the evaporation gauges at the Union Observatory, the Bulawayo Observatory, and the Kenilworth gauge near Kimberley, as well as, through the courtesy of Mr. Lynch, the Manager of the Kimberley Waterworks, Ltd., the gauge at Newton, Kimberley. The following considerations have been based on the records of the first two of these gauges.

Some of these have already been described in scientific journals; their particulars may be summarised as follows:

(1) Union Observatory, Johannesburg; latitude $26^{\circ} 11' S.$, longitude $28^{\circ} 45' E.$, altitude 5924 ft. Square tank about 6 ft. Observations taken by a float and a graduated arc. The gauge is on the top of a hill surrounded by a few trees, which probably interfere with the free movement of the wind. The Observatory building also casts a shadow over the gauge, which might lessen the observed evaporation after 5 p.m.

(2) The Observatory, Bulawayo; latitude $20^{\circ} 09' 1'' S.$, longitude $28^{\circ} 36' 3'' E.$, altitude 4460 ft. above sea-level. Gauge is composed of a circular tank 7 ft. in diameter on the top of a hill well exposed to wind conditions. Records taken from a float on a circular arc.

(3) Dr. Sutton's tank, Kenilworth, Kimberley; latitude $28^{\circ} 42' S.$, longitude $24^{\circ} 47' E.$, altitude about 4000 ft. above sea-level. Observations are taken from a 6-ft. tank built into the ground, from which a pipe is led off into a closed room, where a float records by clockwork. The tank is situated in an area which is sheltered by trees on all sides, and it is thought that the conditions are not ideal for evaporation purposes.

(4) Newton, Kimberley. Observations are taken from a tank about 4 ft. square built into the ground on the top of a hill exposed to every condition, with no surrounding trees. The observations are taken by means of a hook gauge, which permits of readings being directly observed to one thousandth

of an inch. Unfortunately there are no hygrometric observations taken at this gauge.

It will be seen that, although the conditions attending these gauges are dissimilar in several important respects, where the hygrometric conditions are observed in the vicinity of the gauges the evaporation will naturally bear relationship to the observed relative humidity at each.

The author has compiled the information for Johannesburg, Newton, Kimberley, Bulawayo, for five years ending December 31, 1917.

He has unfortunately been unable to secure the records of Dr. Sutton, Kimberley, for this period, and they are therefore not available for comparative purposes in this paper. The records of Newton, Kimberley, can only be looked upon in the light of interesting figures, as owing to there being no psychrometric data available, comparison cannot be drawn between relative humidity and evaporation, which latter is higher; and it can be concluded that, owing to the exposed position of the gauge, the relative humidity will be exceedingly low.

Upon proceeding to plot as a graph the recorded evaporation compared with the recorded relative humidity, the author found that when the evaporation increased, the relative humidity decreased.

Bearing in mind the fact that evaporation does not vary as the relative humidity, he found that a consistent relation obtained in the graph, between the difference of relative humidity and saturation and the recorded evaporation. That is to say E. varied as $100-H$. This factor the author has herein-after referred to as the "deficiency factor." Attention is now invited to the records of Bulawayo and Johannesburg, as shown on the attached series of tabulated statements, from which it will be seen that the mean annual temperature of each place varies considerably with the annual temperature, as follows:

| YEAR. | BULAWAYO. LAT. $20^{\circ} 09' 15''$ S. | | JOHANNESBURG. LAT. $26^{\circ} 11'$ S. | |
|-----------------------|--|--|---|--|
| | MEAN TEMP. Max. + Min. 2 | DIFFERENCE FROM MEAN OF 5 YEARS. | MEAN TEMP. Max. + Min. 2 | DIFFERENCE FROM MEAN OF 5 YEARS. |
| | | | | |
| 1913 | 67.1° | + .54 above | 60.27° | + .498 above |
| 1914 | 67.1° | + .54 " | 60.74° | + .968 " |
| 1915 | 65.9° | - 1.20 below | 59.53° | - .242 below |
| 1916 | 66.5° | - 0.06 " | 60.24° | + .468 above |
| 1917 | 66.2 | - 0.36 " | 58.08 | - 1.692 below |
| MEAN OF FIVE YEARS | 66.56 | + 1.08 - 1.62 | 59.772 | + 1.934 - 1.934 |

The annexed tables show the evaporation in decimals of an inch divided by the "deficiency factor," from which it will be seen that the mean evaporation per annum for five years at Bulawayo is 2.081389 inches per 1 per cent. of deficiency per annum, or .0057024 inches per 1 per cent. of deficiency per diem; whilst for Johannesburg the same figures result in 1.460397 inches and .0040009 per annum and per diem respectively, whilst the mean annual temperature $\frac{(\text{max.} + \text{min.})}{2}$ were 67.1° and 59.7° respectively.

It will be borne in mind also that Bulawayo is 20° 09' 1" S. latitude, and Johannesburg is 26° 11' S.—a difference of 6.2° of latitude; that, assuming all other conditions to be equal, an allowance must be provided for the difference of the intensity of the sun's rays in latitude.

The Smithsonian tables give factors for the relative intensity of solar radiation for the Northern Hemisphere, and the author is informed by Father Goetz at Bulawayo that the same factors can be applied relatively to the Southern Hemisphere.

The factors for the year are as follows: For 20° latitude, 0.289; for 30° latitude, 0.268.

But yet another correction has to be applied, and that is the "hours of sun above the horizon."

Dr. Sutton, in a communication to the 'Agricultural Journal of the Union of South Africa,' gave relative evaporations with sunshine observations from a Campbell-Stokes sunshine recorder, and there appeared to be no actual relation between sunshine and evaporation—a result which can only be expected, inasmuch as a largely increased evaporation must naturally take place during cloudy weather, when the sun is obscured. In fact, many observers state that evaporation takes place to a greater extent when clouds are in the sky, for the simple reason that the heat rays are reflected by clouds, causing the actual temperature to be greater; but it is apparent that the sun is primarily the cause of all heat, and therefore primarily the cause of all evaporation, and from the moment the sun rises above the horizon until it sets evaporation must be going on. Therefore the hours of sun above the horizon must form an important consideration.

Most people are apt to forget that the thermometer is not an index of quantity of heat, since it only registers the momentary effect of heat; hence the time factor has to be brought in, *i. e.* the hours of sun above the horizons and this consideration bears largely on the apparent difference between the evaporation of, say, January and June. At Cape Town, according to the hours of daylight in 'Letts' Diary,' there are in January approximately 14 hours of daylight per diem, or 445 hours of daylight per month, whilst in June there are 9.9 hours and 299 hours respectively for the same periods; and at Johannesburg similar figures for January and June are 13.4 and 10.6 hours per diem, or 418 hours as against 317 hours per month.

Although the factors on the annexed tables give the mean daily evaporation in inches, and although the author concludes as per the preceding paragraph that the evaporation is dependent upon the hours of sunlight, the fact must not be lost sight of that a certain amount of evaporation takes place during the night, owing to terrestrial radiation.

Dr. Sutton has shown that at Kenilworth approximately one-third of the total daily evaporation takes place during the hours of the night.

One point must not be lost sight of, and that is that these results have been based on observations taken at 8.30 a.m. daily, and that the recorded evaporation is that of the whole twenty-four hours of each day. It is quite reasonable to suppose that the relative humidity varies during each hour of the day, so that in the event of records being taken by subsequent observers the E. per deficiency factor may be found to be lower than in these conclusions. The results can therefore only be regarded as relative.

The author has annexed a table based upon Dr. Sutton's figures showing the mean annual evaporation for each hour of the twenty-four at Kimberley, and as an additional proof that evaporation follows closely upon the 'deficiency factor' of humidity the lines of this factor per hour are shown.

In presenting this paper to the Society the author has refrained from evolving a formula, being content to show the recorded evaporation at gauges that he has seen and considers to be the best available ones existing.

He trusts that he has made it clear.

It is to be hoped that meteorologists and engineers will follow up by further research on the lines above indicated, with the view to the establishment of a formula which will not be only suitable to Africa, but to the whole world.

EVAPORATION · THE OBSERVATORY · BULAWAYO.

LAT. 20° 09' 15" LONG. 28° 36' 31" ALT. 4460 FT

SUMMARY OF OBSERVATIONS FOR PERIOD OF FIVE YEARS.

| YEAR | EVAPORATION TOTAL INCHES PER ANNUM. | WIND MEAN MILES PER DIEM. | MEAN ANNUAL TEMPERATURE MO. & MIN. DEGREES F. | MEAN ANNUAL RELATIVE HUMIDITY. H % | MEAN ANNUAL DEFICIENCY OF RELATIVE HUMIDITY 100 - H. | MEAN ANNUAL EVAPORATION IN INCHES PER DEFICIENCY OF RELATIVE HUMIDITY. | MEAN DAILY EVAPORATION IN INCHES PER DEFICIENCY OF RELATIVE HUMIDITY |
|------------------------|---|------------------------------------|--|---|---|---|---|
| 1913. | 83.30. | 171.6. | 67.1. | 59. | 41. | 2.031707. | .0055663. |
| 1914. | 76.47. | 192.0. | 67.1. | 64. | 36. | 2.124167. | .0058197. |
| 1915. | 66.32. | 176.4. | 65.9. | 69. | 31. | 2.139355. | .0058612. |
| 1916. | 76.62. | 179.1. | 66.5. | 63. | 37. | 2.070808. | .0056579. |
| 1917. | 71.94. | 180.5. | 66.2. | 65. | 35. | 2.055429. | .0056313. |
| MEAN OF FIVE YEARS. | 74.93. | 179.92. | 66.56. | 64. | 36. | 2.081389. | .0057024. |

TABLE 1.

EVAPORATION · THE OBSERVATORY BULAWAYO ·

LAT. 20° 09' 15" LONG. 28° 36' 3" E ALT. 4460 FT

OBSERVATIONS FOR 1913.

| 1913. | EVAPORATION | WIND | MEAN | MEAN DAILY | MEAN DAILY | MEAN MONTHLY | MEAN DAILY |
|--------|-------------|------------------------|--|----------------------------|--|---|---|
| | INCHES. | MEAN MILES PER DIEM | TEMPERATURE Max & Min 2 Degrees. F. | RELATIVE HUMIDITY H% | DEFICIENCY OF RELATIVE HUMIDITY 100 - H. | EVAPORATION IN INCHES PER % DEFICIENCY OF RELATIVE HUMIDITY | EVAPORATION IN INCHES PER % DEFICIENCY OF RELATIVE HUMIDITY |
| JAN. | 8.94 | 183.9 | 73.7 | 60 | 40 | .223500 | .0072096 |
| FEB. | 5.45 | 178.3 | 72.1 | 79 | 21 | .259524 | .0092687 |
| MAR. | 6.64 | 185.4 | 68.7 | 69 | 31 | .214193 | .0063094 |
| APR. | 5.04 | 145.2 | 66.8 | 76 | 24 | .210000 | .0070000 |
| MAY. | 5.38 | 145.6 | 62.1 | 66 | 34 | .158235 | .0051043 |
| JUN. | 4.36 | 155.5 | 55.5 | 63 | 37 | .117838 | .0039279 |
| JUL. | 4.39 | 109.7 | 58.4 | 50 | 50 | .087800 | .0028323 |
| AUG. | 5.98 | 172.1 | 62.0 | 50 | 50 | .119000 | .0038387 |
| SEP. | 8.89 | 226.1 | 67.2 | 50 | 50 | .177800 | .0059267 |
| OCT. | 9.65 | 216.0 | 71.8 | 50 | 50 | .193000 | .0062258 |
| NOV. | 7.99 | 176.8 | 70.1 | 59 | 41 | .194878 | .0064859 |
| DEC. | 10.62 | 165.8 | 76.0 | 45 | 55 | .195091 | .0062287 |
| MEAN. | .. | 171.6 | 67.1 | 59 | 41 | .. | .0055663 |
| TOTAL. | 83.30 | .. | .. | .. | .. | 2.031707 | .. |

TABLE 2.

EVAPORATION · THE OBSERVATORY · BULAWAYO ·

LAT 20° 09' 15" LONG. 28° 36' 3" E ALT. 4460 FT

OBSERVATIONS FOR 1914.

| 1914. | EVAPORATION | WIND | MEAN | MEAN DAILY | MEAN DAILY | MEAN MONTHLY | MEAN DAILY |
|--------|-------------|------------------------|--|----------------------------|--|---|---|
| | INCHES. | MEAN MILES PER DIEM | TEMPERATURE Max & Min 2 Degrees. F. | RELATIVE HUMIDITY H% | DEFICIENCY OF RELATIVE HUMIDITY 100 - H. | EVAPORATION IN INCHES PER % DEFICIENCY OF RELATIVE HUMIDITY | EVAPORATION IN INCHES PER % DEFICIENCY OF RELATIVE HUMIDITY |
| JAN. | 7.94 | 168.3 | 73.9 | 65. | 35 | .226857 | .0073172 |
| FEB. | 4.81 | 192.1 | 69.6 | 86 | 14 | .343571 | .0122704 |
| MAR. | 6.64 | 193.1 | 70.1 | 67 | 33 | .201212 | .0064907 |
| APR. | 6.38 | 176.4 | 69.3 | 68 | 32 | .199375 | .0066458 |
| MAY. | 5.03 | 149.7 | 62.3 | 69 | 31 | .162258 | .0052341 |
| JUN. | 4.40 | 181.0 | 58.8 | 52 | 48 | .091667 | .0030556 |
| JUL. | 3.63 | 170.5 | 55.5 | 66 | 34 | .106765 | .0034440 |
| AUG. | 5.17 | 218.8 | 59.4 | 65 | 35 | .147774 | .0047650 |
| SEP. | 8.97 | 210.3 | 70.5 | 48 | 52 | .172500 | .0057500 |
| OCT. | 10.73 | 257.1 | 74.2 | 45 | 55 | .195454 | .0063050 |
| NOV. | 8.17 | 216.2 | 73.0 | 53 | 47 | .173829 | .0047943 |
| DEC. | 4.58 | 150.8 | 71.4 | 83 | 17 | .269412 | .0086917 |
| MEAN. | .. | 192.0 | 67.1 | 64 | 36 | .. | .0058197 |
| TOTAL. | 76.47 | .. | .. | .. | .. | 2.124167 | .. |

TABLE 3.

EVAPORATION - THE OBSERVATORY BULAWAYO.

LAT. 20° 09' 15" LONG. 28° 36' 3" E. ALT. 4460 FT.

OBSERVATIONS FOR 1915

| 1915 | EVAPORATION INCHES. | WIND MEAN MILES PER DIEM. | MEAN TEMPERATURE Max & Min Degrees F. | MEAN DAILY RELATIVE HUMIDITY H% | MEAN DAILY DEFICIENCY OF RELATIVE HUMIDITY 100 - H. | MEAN MONTHLY EVAPORATION IN INCHES. PER % DEFICIENCY OF RELATIVE HUMIDITY. | MEAN DAILY EVAPORATION IN INCHES. PER % DEFICIENCY OF RELATIVE HUMIDITY. |
|--------|------------------------|---------------------------------|--|--|--|---|---|
| JAN. | 4.63 | 125.7 | 70.9 | 92 | 08 | 578750 | .0186694 |
| FEB. | 4.46 | 153.1 | 68.5 | 87 | 13 | 343077 | .0122528 |
| MAR. | 4.35 | 169.1 | 66.1 | 80 | 20 | 217500 | .0070161 |
| APR. | 5.30 | 123.7 | 66.4 | 72 | 28 | 189286 | .0063095 |
| MAY. | 3.90 | 191.3 | 59.9 | 77 | 23 | 169565 | .0054699 |
| JUN. | 3.69 | 166.3 | 57.0 | 71 | 29 | 127241 | .0042414 |
| JUL. | 3.92 | 166.5 | 61.2 | 71 | 29 | 135172 | .0043604 |
| AUG. | 3.44 | 195.5 | 60.8 | 62 | 38 | 143158 | .0046180 |
| SEP. | 4.44 | 236.1 | 66.3 | 54 | 46 | 140000 | .0046667 |
| OCT. | 6.39 | 246.7 | 70.9 | 50 | 50 | 167800 | .0054129 |
| NOV. | 7.47 | 202.8 | 72.1 | 53 | 47 | 158936 | .0052979 |
| DEC. | 8.33 | 202.1 | 72.3 | 58 | 42 | 198333 | .0063978 |
| MEAN | - | 176.4 | 65.8 | 69 | 31 | - | .0058612 |
| TOTAL. | 66.32 | - | - | - | - | 2.139355 | - |

TABLE 4.

EVAPORATION - THE OBSERVATORY BULAWAYO.

LAT. 20° 09' 15" LONG. 28° 36' 3" E. ALT. 4460 FT.

OBSERVATIONS FOR 1916.

| 1916. | EVAPORATION INCHES. | WIND MEAN MILES PER DIEM. | MEAN TEMPERATURE Max & Min Degrees F. | MEAN DAILY RELATIVE HUMIDITY H% | MEAN DAILY DEFICIENCY OF RELATIVE HUMIDITY 100 - H. | MEAN MONTHLY EVAPORATION IN INCHES. PER % DEFICIENCY OF RELATIVE HUMIDITY. | MEAN DAILY EVAPORATION IN INCHES. PER % DEFICIENCY OF RELATIVE HUMIDITY. |
|--------|------------------------|---------------------------------|--|--|--|---|---|
| JAN. | 8.23 | 171.0 | 70.9 | 76 | 24 | 342917 | .0110619 |
| FEB. | 7.74 | 161.1 | 73.5 | 58 | 42 | 184286 | .0063546 |
| MAR. | 6.75 | 173.2 | 70.2 | 72 | 28 | 241071 | .0077765 |
| APR. | 5.06 | 160.5 | 65.1 | 70 | 30 | 168666 | .0056222 |
| MAY. | 4.93 | 145.2 | 59.7 | 66 | 34 | 145000 | .0046774 |
| JUN. | 3.79 | 142.7 | 58.0 | 60 | 40 | 094500 | .0031500 |
| JUL. | 4.63 | 178.8 | 58.3 | 62 | 38 | 121842 | .0038304 |
| AUG. | 5.01 | 191.0 | 59.6 | 50 | 50 | 100200 | .0032323 |
| SEP. | 7.48 | 202.9 | 67.5 | 44 | 56 | 133571 | .0044524 |
| OCT. | 9.34 | 237.2 | 73.7 | 50 | 50 | 198800 | .0064129 |
| NOV. | 7.38 | 207.9 | 71.2 | 63 | 37 | 199459 | .0066486 |
| DEC. | 5.68 | 173.1 | 69.9 | 80 | 20 | 284000 | .0091613 |
| MEAN | - | 179.1 | 66.5 | 63 | 37 | - | .0056579 |
| TOTAL. | 76.62 | - | - | - | - | 2.070808 | - |

TABLE 5.

EVAPORATION · THE OBSERVATORY BULAWAYO ·

LAT. 20° 09' S. LONG. 28° 36' E. ALT. 4460 FT.

OBSERVATIONS FOR 1917.

| 1917. | EVAPORATION INCHES. | WIND MEAN MILES PER DIEM. | MEAN TEMPERATURE Max & Min. ° Degrees F. | MEAN DAILY RELATIVE HUMIDITY H% | MEAN DAILY DEFICIENCY OF RELATIVE HUMIDITY 100 - H. | MEAN MONTHLY EVAPORATION IN INCHES PER % DEFICIENCY OF RELATIVE HUMIDITY. | MEAN DAILY EVAPORATION IN INCHES PER % DEFICIENCY OF RELATIVE HUMIDITY. |
|---------------|------------------------|---------------------------------|---|--|--|--|--|
| JAN. | 6.42 | 178.0 | 69.6 | 72 | 28 | .225286 | .0073963 |
| FEB. | 6.49 | 176.0 | 70.9 | 66 | 34 | .190882 | .0068172 |
| MAR. | 6.21 | 207.4 | 68.9 | 69 | 31 | .200323 | .0064640 |
| APR. | 5.19 | 150.6 | 65.3 | 73 | 27 | .192222 | .0064074 |
| MAY. | 3.63 | 136.8 | 60.7 | 75 | 25 | .153200 | .0043419 |
| JUN. | 4.08 | 111.4 | 58.1 | 57 | 43 | .034884 | .0031626 |
| JUL. | 4.14 | 127.7 | 57.3 | 61 | 39 | .106154 | .0034243 |
| AUG. | 5.32 | 219.4 | 60.7 | 66 | 34 | .156470 | .0050474 |
| SEP. | 7.37 | 241.5 | 66.6 | 64 | 36 | .204722 | .0068240 |
| OCT. | 9.51 | 215.1 | 73.8 | 45 | 55 | .172909 | .0055777 |
| NOV. | 8.01 | 204.8 | 72.8 | 63 | 37 | .216466 | .0072162 |
| DEC. | 5.17 | 133.2 | 68.4 | 83 | 17 | .304116 | .0058103 |
| MEAN TOTAL | 71.94 | 180.5 | 66.2 | 66 | 35 | 2.055429 | .0066313 |

TABLE 6.

EVAPORATION · UNION OBSERVATORY · JOHANNESBURG ·

LAT 26° 11' S. LONG. 28° 4' S. E. ALT. 5924 FT.

SUMMARY OF OBSERVATIONS FOR PERIOD OF FIVE YEARS.

| YEAR. | EVAPORATION TOTAL INCHES PER ANNUM. | WIND MEAN MILES PER DIEM. | MEAN ANNUAL TEMPERATURE max - min ° Degrees F. | MEAN ANNUAL RELATIVE HUMIDITY H% | MEAN ANNUAL DEFICIENCY OF RELATIVE HUMIDITY 100 - H. | MEAN ANNUAL EVAPORATION IN INCHES PER % DEFICIENCY OF RELATIVE HUMIDITY. | MEAN DAILY EVAPORATION IN INCHES PER % DEFICIENCY OF RELATIVE HUMIDITY. |
|-----------------------|---|------------------------------------|---|---|---|---|--|
| 1913. | 68.55 | 317.2 | 60.27 | 56.28 | 43.72 | 1.567932 | .0042957 |
| 1914 | 66.12 | 262.2 | 60.74 | 58.18 | 41.82 | 1.581062 | .0043317 |
| 1915 | 55.60 | 277.4 | 59.53 | 60.00 | 40.00 | 1.390000 | .0038082 |
| 1916 | 61.76 | 279.6 | 60.24 | 52.53 | 47.47 | 1.301032 | .0035644 |
| 1917. | 54.04 | 274.0 | 58.08 | 63.03 | 36.97 | 1.461726 | .0040047 |
| MEAN OF FIVE YEARS | 61.214 | 282.08 | 59.772 | 58.004 | 41.996 | 1.460397 | .0040009 |

TABLE 7.

EVAPORATION-UNION OBSERVATORY-JOHANNESBURG.

LAT 26°11'S LONG 28°45'E, ALT. 5924 FT.

OBSERVATIONS FOR 1913.

| 1913. | EVAPORATION INCHES | WIND MEAN MILES per diem | MEAN TEMPERATURE <small>max + min 2</small> DEGREES F. | MEAN DAILY RELATIVE HUMIDITY H 20 | MEAN DAILY DEFICIENCY RELATIVE HUMIDITY 100-H | MEAN MONTHLY EVAPORATION INCHES, PER 1% DEFICIENCY OF RELATIVE HUMIDITY | MEAN DAILY EVAPORATION INCHES, PER 1% DEFICIENCY OF RELATIVE HUMIDITY |
|-------|-----------------------|--------------------------------|---|--|---|--|--|
| JAN. | 6.46 | 331.2 | 66.1 | 65.8 | 34.2 | 188889 | 0060932 |
| FEB. | 5.39 | 292.8 | 65.9 | 72.0 | 28.0 | 192500 | 0068750 |
| MAR. | 5.17 | 276.0 | 62.2 | 71.8 | 28.2 | 183333 | 0059139 |
| APR. | 4.00 | 244.8 | 60.2 | 69.6 | 30.4 | 131578 | 0043859 |
| MAY. | 4.43 | 319.2 | 54.6 | 48.4 | 51.6 | 085853 | 0027694 |
| JUN. | 3.91 | 312.0 | 51.1 | 48.1 | 51.9 | 075337 | 0025112 |
| JUL. | 4.72 | 324.0 | 53.8 | 38.4 | 61.6 | 076623 | 0024717 |
| AUG. | 5.62 | 352.8 | 56.0 | 43.6 | 56.4 | 099645 | 0032143 |
| SEP. | 6.54 | 355.2 | 58.3 | 41.3 | 58.7 | 111414 | 0037138 |
| OCT. | 7.18 | 357.6 | 61.6 | 36.5 | 43.5 | 165057 | 0053244 |
| NOV. | 6.76 | 290.4 | 65.0 | 61.1 | 38.9 | 173759 | 0057926 |
| DEC. | 8.37 | 350.4 | 66.4 | 58.8 | 41.2 | 203155 | 0065534 |
| MEAN. | .. | 317.2 | 60.27 | 56.28 | 43.72 | .. | 0042957 |
| TOTAL | 68.55 | .. | .. | .. | .. | 1567932 | .. |

TABLE 8.

EVAPORATION-UNION OBSERVATORY-JOHANNESBURG

LAT 26°11'S LONG 28°45'E, ALT. 5924 FT.

OBSERVATIONS FOR 1914

| 1914 | EVAPORATION INCHES | WIND MILES PER DIEM | MEAN TEMPERATURE <small>max + min 2</small> DEGREES F. | MEAN DAILY RELATIVE HUMIDITY H 20 | MEAN DAILY DEFICIENCY RELATIVE HUMIDITY 100-H | MEAN MONTHLY EVAPORATION INCHES, PER 1% DEFICIENCY OF RELATIVE HUMIDITY | MEAN DAILY EVAPORATION INCHES, PER 1% DEFICIENCY OF RELATIVE HUMIDITY |
|-------|-----------------------|---------------------------|---|--|---|--|--|
| JAN. | 6.65 | 300.0 | 69.3 | 63.2 | 36.8 | 180706 | 0058292 |
| FEB. | 6.43 | 266.4 | 67.0 | 67.6 | 32.4 | 198457 | 0070877 |
| MAR. | 5.27 | 240.0 | 64.8 | 66.2 | 33.8 | 155917 | 0050296 |
| APR. | 5.16 | 247.2 | 61.9 | 61.1 | 38.9 | 132648 | 0044216 |
| MAY. | 3.80 | 206.4 | 56.6 | 56.1 | 43.9 | 086560 | 0027923 |
| JUN. | 3.33 | 213.6 | 49.9 | 53.0 | 47.0 | 070851 | 0023617 |
| JUL. | 4.11 | 220.8 | 52.2 | 38.2 | 61.8 | 066505 | 0021453 |
| AUG. | 4.74 | 266.4 | 51.2 | 48.1 | 51.9 | 091329 | 0029461 |
| SEP. | 7.21 | 302.4 | 64.3 | 41.4 | 58.6 | 123038 | 0041013 |
| OCT. | 6.32 | 288.0 | 63.7 | 60.3 | 39.7 | 159194 | 0051356 |
| NOV. | 7.63 | 333.6 | 62.0 | 64.2 | 35.8 | 213126 | 0071043 |
| DEC. | 5.47 | 261.6 | 66.0 | 78.8 | 21.2 | 258019 | 0083229 |
| MEAN. | .. | 262.2 | 60.74 | 58.18 | 41.82 | .. | 0093317 |
| TOTAL | 66.12 | .. | .. | .. | .. | 1581062 | .. |

TABLE 9.

EVAPORATION-UNION OBSERVATORY JOHANNESBURG.

LAT 26° 11' S. LONG 28° 43' E ALT 5924 FT.

OBSERVATIONS FOR 1915.

| 1915 | EVAPORATION INCHES. | WIND MILES PER DIEM | MEAN TEMPERATURE <small>max. + min.</small> DEGREES F. | MEAN DAILY RELATIVE HUMIDITY H% | MEAN DAILY DEFICIENCY OF RELATIVE HUMIDITY. 100-H. | MEAN MONTHLY EVAPORATION INCHES PER 1% DEFICIENCY OF RELATIVE HUMIDITY | MEAN DAILY EVAPORATION INCHES PER 1% DEFICIENCY OF RELATIVE HUMIDITY |
|--------|------------------------|---------------------------|---|--|--|---|---|
| JAN. | 4.46 | 268.8 | 66.7 | 84.0 | 16.0 | .278750 | .0089919 |
| FEB. | 4.20 | 223.2 | 67.0 | 69.4 | 30.6 | .137255 | .0049020 |
| MAR. | 5.27 | 218.4 | 65.6 | 60.1 | 39.9 | .132080 | .0042606 |
| APR. | 5.07 | 273.6 | 61.0 | 51.3 | 48.7 | .104107 | .0034702 |
| MAY | 3.27 | 297.6 | 53.6 | 59.2 | 40.8 | .080147 | .0028854 |
| JUN. | 3.06 | 232.0 | 50.4 | 48.6 | 51.4 | .059533 | .0018844 |
| JUL. | 1.82 | 278.4 | 48.0 | 66.1 | 33.9 | .053687 | .0017318 |
| AUG. | 3.83 | 264.0 | 54.8 | 48.3 | 51.7 | .074081 | .0023897 |
| SEP. | 5.50 | 536.0 | 58.0 | 51.0 | 49.0 | .112245 | .0037415 |
| OCT. | 6.91 | 336.0 | 61.2 | 53.4 | 46.6 | .148283 | .0046833 |
| NOV. | 5.80 | 280.8 | 63.6 | 61.5 | 38.5 | .150649 | .0050216 |
| DEC. | 6.41 | 300.0 | 64.5 | 67.2 | 32.8 | .195427 | .0063041 |
| MEAN. | .. | 277.4 | 55.53 | 60.0 | 40.0 | .. | .0038082 |
| TOTAL. | 55.60 | .. | .. | .. | .. | 1.39000 | .. |

TABLE 10.

EVAPORATION-UNION OBSERVATORY JOHANNESBURG.

LAT. 26° 11' S. LONG 28° 43' E. ALT. 5924 FT.

OBSERVATIONS FOR 1916.

| 1916 | EVAPORATION INCHES. | WIND MEAN MILES per diem | MEAN TEMPERATURE <small>max. + min.</small> DEGREES F. | MEAN DAILY RELATIVE HUMIDITY H% | MEAN DAILY DEFICIENCY OF RELATIVE HUMIDITY 100-H. | MEAN MONTHLY EVAPORATION INCHES PER 1% DEFICIENCY OF RELATIVE HUMIDITY | MEAN DAILY EVAPORATION INCHES PER 1% DEFICIENCY OF RELATIVE HUMIDITY |
|--------|------------------------|--------------------------------|---|--|---|---|---|
| JAN. | 5.85 | 268.8 | 66.1 | 64.6 | 35.4 | .165254 | .0053308 |
| FEB. | 6.31 | 261.6 | 67.5 | 59.7 | 40.3 | .154575 | .0053991 |
| MAR. | 3.96 | 242.4 | 63.5 | 70.0 | 30.0 | .132000 | .0042580 |
| APR. | 4.16 | 244.8 | 60.9 | 55.0 | 45.0 | .092444 | .0030614 |
| MAY | 3.97 | 280.8 | 52.7 | 47.0 | 53.0 | .074906 | .0024163 |
| JUN. | 3.89 | 283.2 | 53.1 | 37.4 | 62.6 | .062140 | .0020713 |
| JUL. | 4.00 | 280.8 | 52.3 | 43.5 | 56.5 | .070796 | .0021837 |
| AUG. | 5.16 | 321.6 | 52.6 | 37.8 | 62.2 | .082958 | .0026760 |
| SEP. | 6.70 | 328.8 | 60.5 | 31.8 | 68.2 | .098240 | .0032746 |
| OCT. | 6.18 | 292.8 | 66.3 | 47.0 | 53.0 | .116604 | .0037614 |
| NOV. | 6.16 | 280.8 | 63.6 | 61.5 | 38.5 | .160000 | .0053333 |
| DEC. | 5.42 | 268.8 | 63.8 | 75.0 | 25.0 | .216000 | .0069935 |
| MEAN. | .. | 279.6 | 60.24 | 52.53 | 47.47 | .. | .0035644 |
| TOTAL. | 61.76 | .. | .. | .. | .. | 1.301032 | .. |

TABLE 11.

EVAPORATION·UNION OBSERVATORY·JOHANNESBURG·

LAT. 26° 11' S. LONG. 28° 45' E. ALT. 5924 FT

OBSERVATIONS FOR 1917.

| 1917 | EVAPORATION INCHES | WIND MEAN MILES per hour | MEAN TEMPERATURE MAXIMUM E 24 HOURS ° F | MEAN DAILY RELATIVE HUMIDITY H. % | MEAN DAILY DEFICIENCY OF RELATIVE HUMIDITY 100-H | MEAN MONTHLY EVAPORATION INCHES PER % DEFICIENCY OF RELATIVE HUMIDITY | MEAN DAILY EVAPORATION INCHES PER % DEFICIENCY OF RELATIVE HUMIDITY |
|-------|-----------------------|--------------------------------|--|--|--|--|--|
| JAN. | 5.63 | 256.8 | 66.6 | 67.7 | 32.3 | 174.503 | 0056227 |
| FEB. | 4.42 | 271.2 | 64.1 | 71.5 | 28.5 | 155.088 | 0055389 |
| MAR. | 4.18 | 247.2 | 64.3 | 63.8 | 36.2 | 115.469 | 0037248 |
| APR. | 4.33 | 254.4 | 57.8 | 63.5 | 36.5 | 118.630 | 0038248 |
| MAY | 3.81 | 247.2 | 54.2 | 52.7 | 47.3 | 080.550 | 0025984 |
| JUN. | 2.90 | 278.4 | 49.8 | 56.6 | 43.4 | 066.820 | 0022273 |
| JUL. | 3.09 | 316.8 | 47.0 | 53.8 | 46.2 | 066.883 | 0021575 |
| AUG. | 3.23 | 276.0 | 49.2 | 63.8 | 36.2 | 089.226 | 0028783 |
| SEP. | 4.55 | 304.8 | 56.7 | 63.8 | 36.2 | 125.650 | 0041896 |
| OCT. | 7.16 | 304.8 | 63.7 | 49.1 | 50.9 | 140.668 | 0045377 |
| NOV. | 6.17 | 285.6 | 61.0 | 72.4 | 27.6 | 223.551 | 0074577 |
| DEC. | 4.57 | 244.8 | 62.6 | 77.6 | 22.4 | 204.018 | 0065812 |
| MEAN. | - | 274.0 | 58.08 | 63.03 | 36.97 | - | 0040047 |
| TOTAL | 54.04 | - | - | - | - | 1461.726 | - |

TABLE 12.

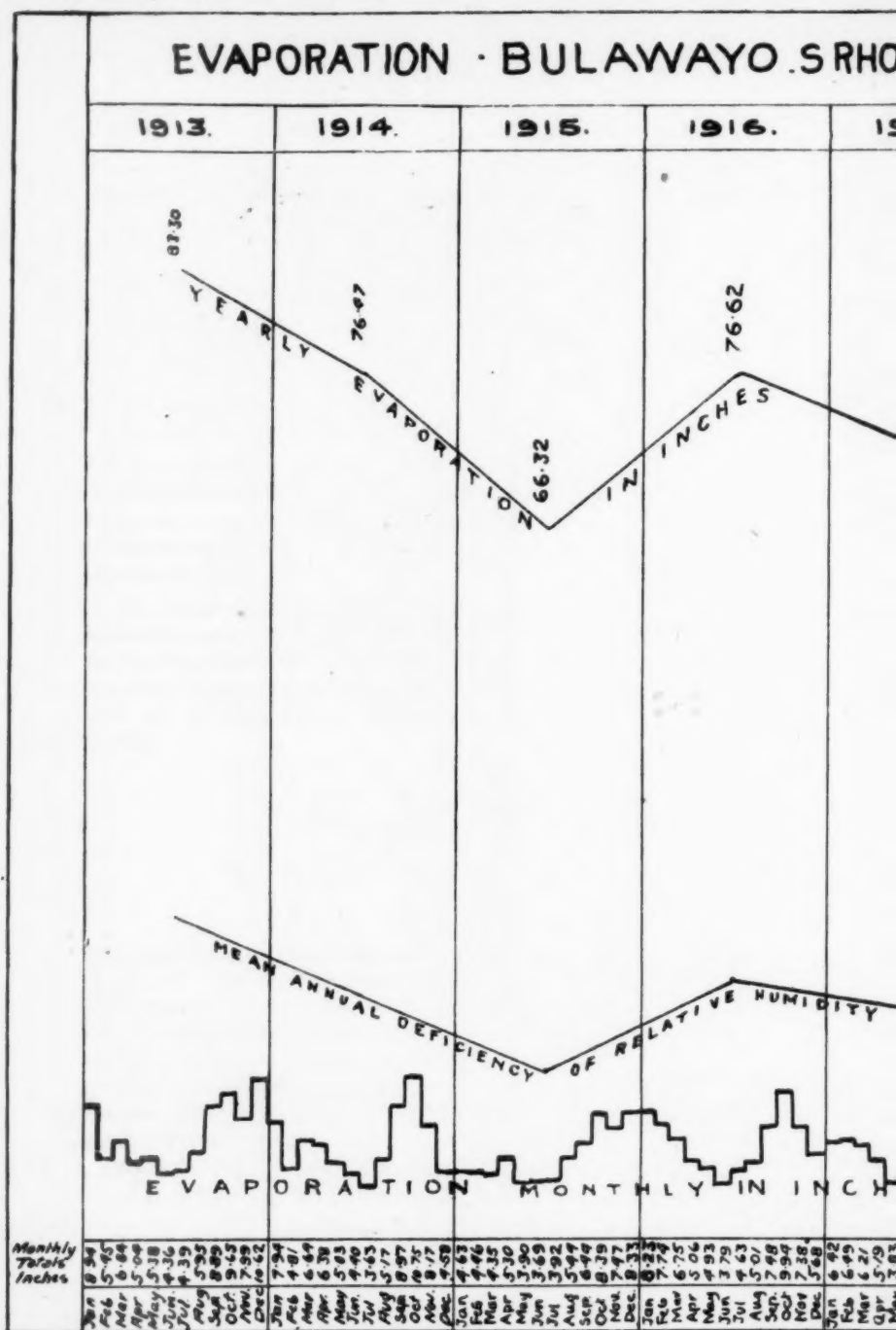
KENILWORTH·KIMBERLEY

MEAN ANNUAL EVAPORATION FOR EACH HOUR PER DIEM.

FROM D^r SUTTONS' PAPER TO THE SOCIETY FOR ADVANCEMENT OF SCIENCE 1904.

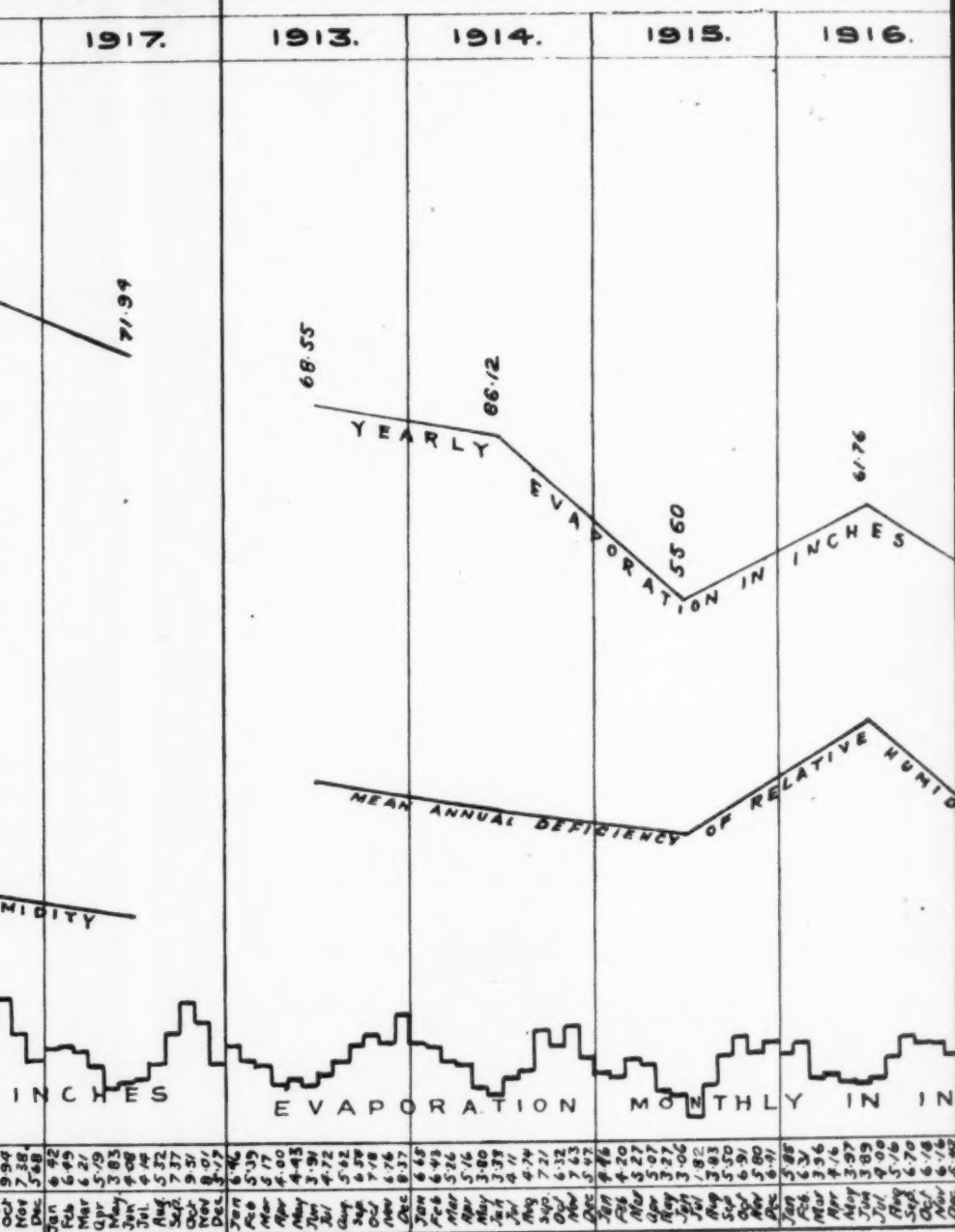
| HOURL | MEAN * ANNUAL EVAPORATION INCHES | MEAN * DAILY EVAPORATION INCHES | MEAN * RELATIVE HUMIDITY H. % | MEAN * TEMPERATURE ° Fahr | MEAN DEFICIENCY OF HUMIDITY 100-H % | MEAN ANNUAL EVAPORATION PER 1% OF DEFICIENCY | MEAN DAILY EVAPORATION PER 1% OF DEFICIENCY |
|------------|---|--|--|---------------------------------|--|---|--|
| I | 1.980 | 000403 | 62.00 | 55.70 | 38.00 | 03899 | 0001066 |
| II | 1.979 | 000403 | 64.20 | 54.55 | 35.80 | 04117 | 0001128 |
| III | 1.930 | 000391 | 64.15 | 53.50 | 33.85 | 04224 | 0001157 |
| IV | 1.917 | 000388 | 67.70 | 52.60 | 37.30 | 04366 | 0001201 |
| V | 1.901 | 000383 | 69.20 | 51.75 | 30.80 | 04598 | 0001246 |
| VI | 1.985 | 000406 | 70.75 | 51.30 | 29.25 | 05076 | 0001390 |
| VII | 1.759 | 000481 | 70.00 | 52.50 | 30.00 | 05863 | 0001406 |
| VIII | 1.892 | 000518 | 63.80 | 56.50 | 36.20 | 05286 | 0001931 |
| IX | 2.031 | 000582 | 54.80 | 62.05 | 37.90 | 04517 | 0001357 |
| X | 2.497 | 000670 | 47.05 | 66.35 | 32.95 | 04621 | 0001266 |
| XI | 3.097 | 000825 | 41.70 | 70.75 | 29.30 | 05157 | 0001915 |
| XII (mean) | 3.688 | 001010 | 37.70 | 73.65 | 26.30 | 05919 | 0001621 |
| XIII | 4.387 | 001201 | 35.85 | 75.70 | 24.30 | 06958 | 0001875 |
| XIV | 4.783 | 001310 | 33.30 | 76.85 | 23.15 | 07140 | 0001961 |
| XV | 4.803 | 001315 | 32.65 | 77.20 | 22.80 | 07151 | 0001983 |
| XVI | 4.398 | 001202 | 33.20 | 76.65 | 23.35 | 06548 | 0001799 |
| XVII | 3.710 | 001016 | 36.40 | 74.40 | 25.60 | 05935 | 0001598 |
| XVIII | 2.854 | 000781 | 41.85 | 70.45 | 28.55 | 04907 | 0001344 |
| XIX | 2.245 | 000615 | 44.95 | 66.40 | 33.05 | 04232 | 0001159 |
| XX | 1.935 | 000530 | 50.85 | 63.50 | 36.50 | 03913 | 0001072 |
| XXI | 1.819 | 000498 | 53.00 | 61.45 | 38.55 | 03670 | 0001060 |
| XXII | 1.731 | 000474 | 55.30 | 59.70 | 40.30 | 03872 | 0001061 |
| XXIII | 1.777 | 000470 | 57.55 | 58.15 | 41.85 | 04044 | 0001108 |
| XXIV | 1.529 | 000419 | 59.75 | 56.85 | 43.15 | 03798 | 0001040 |

NOTE: D^r Suttons' data marked * thus.



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EVAPORATION JOHANNESBURG OBSER

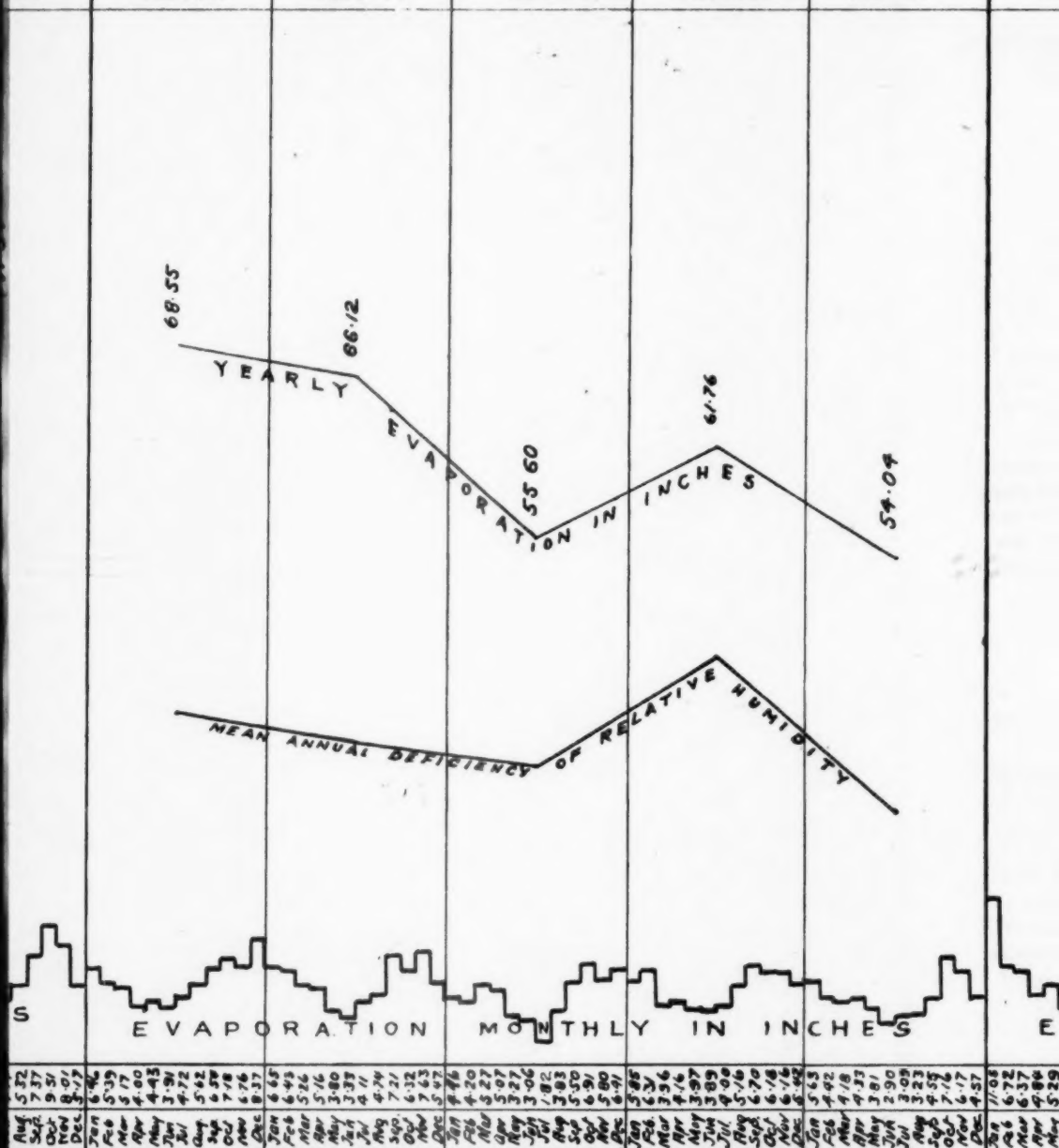


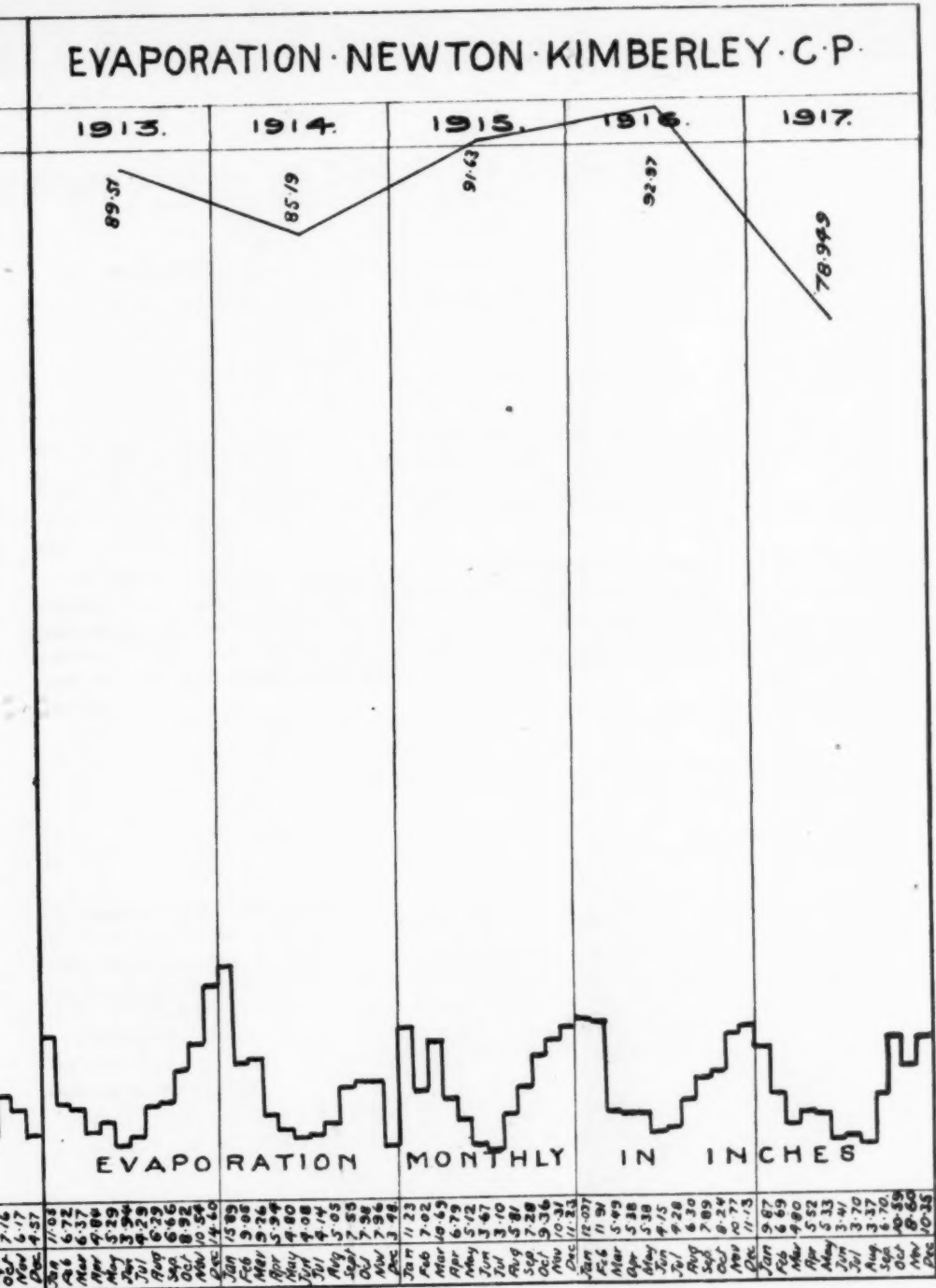
ESIA.

EVAPORATION JOHANNESBURG OBSERVATORY.

EY

7. 1913. 1914. 1915. 1916. 1917. 19





SECOND NOTE ON THE DETERMINANT OF THE SUM OF TWO CIRCULANT MATRICES.

BY SIR THOMAS MUIR, LL.D.

(1) Almost forty years ago the curious identity

$$\begin{vmatrix} 1 & a_2+b_2 & a_3+b_3 & a_4+b_4 & a_5+b_5 \\ 1 & a_1+b_3 & a_2+b_4 & a_3+b_5 & a_4+b_1 \\ 1 & a_5+b_4 & a_1+b_5 & a_2+b_1 & a_3+b_2 \\ 1 & a_4+b_5 & a_5+b_1 & a_1+b_2 & a_2+b_3 \\ 1 & a_3+b_1 & a_4+b_2 & a_5+b_3 & a_1+b_4 \end{vmatrix} = \begin{vmatrix} 1 & a_2-b_2 & a_3-b_3 & a_4-b_4 & a_5-b_5 \\ 1 & a_1-b_3 & a_2-b_4 & a_3-b_5 & a_4-b_1 \\ 1 & a_5-b_4 & a_1-b_5 & a_2-b_1 & a_3-b_2 \\ 1 & a_4-b_5 & a_5-b_1 & a_1-b_2 & a_2-b_3 \\ 1 & a_3-b_1 & a_4-b_2 & a_5-b_3 & a_1-b_4 \end{vmatrix}$$

was pointedly drawn attention to* in the hope that a purely determinant proof might be forthcoming. In the long-continued absence of such a proof I propose to supply one, not so much, however, on account of the importance of the identity itself as of the incidental and subsequent theorems to which the attempt has led up.

(2) At the outset it is clear that each of the two determinants involved is expressible as a sum of sixteen (2^4) determinants with monomial elements: and, further, that as they differ only in the signs of the b 's, a number of the one set of sixteen must cancel the same number of the other set. For shortness' sake and definiteness of statement let us denote the sixteen on the left, namely,

$$\begin{vmatrix} 1 & a_2 & a_3 & a_4 & a_5 \\ 1 & a_1 & a_2 & a_3 & a_4 \\ 1 & a_5 & a_1 & a_2 & a_3 \\ 1 & a_4 & a_5 & a_1 & a_2 \\ 1 & a_3 & a_4 & a_5 & a_1 \end{vmatrix}, \begin{vmatrix} 1 & a_2 & a_3 & a_4 & b_5 \\ 1 & a_1 & a_2 & a_3 & b_1 \\ 1 & a_5 & a_1 & a_2 & b_2 \\ 1 & a_4 & a_5 & a_1 & b_3 \\ 1 & a_3 & a_4 & a_5 & b_1 \end{vmatrix}, \dots$$

by

$$|011111|, |011112|, \dots$$

the constant column being indicated by 0, a column of a 's by 1, and a column of b 's by 2. We then see that, if in the symbol for a determinant on the right there be an even number of 2's, the said determinant cannot differ from the corresponding determinant on the left; and if there be an odd number of 2's the difference existing is merely a difference of sign. It thus follows by subtraction that what we are reduced to showing is that the double of the sum of the determinants on the right that have an odd number of 2's is equal to 0: that is, that

$$2\{ |011112| + |011211| + |012111| + |012221| + |021111| + |021222| + |022112| + |022211| \} = 0.$$

* 'Analyst,' x (1882), pp. 8-9.

In the next place, it being impossible that a determinant with one 2 in its symbol—that is, with one column of b 's—can have any of its terms cancelled by terms of a determinant with three columns of b 's, we infer that we are face to face with *two* vanishing aggregates, namely,

$$|0\ 1\ 1\ 1\ 2| + |0\ 1\ 1\ 2\ 1| + |0\ 1\ 2\ 1\ 1| + |0\ 2\ 1\ 1\ 1| = 0$$

and

$$|0\ 1\ 2\ 2\ 2| + |0\ 2\ 1\ 2\ 2| + |0\ 2\ 2\ 1\ 2| + |0\ 2\ 2\ 2\ 1| = 0.$$

It is seen, however, on a second glance that either of these is got from the other by merely interchanging a 's and b 's, so that in reality there is only one to be proved, the full-length form of which is

$$0 = \begin{vmatrix} 1 & a_2 & a_3 & a_4 & b_5 \\ 1 & a_1 & a_2 & a_3 & b_1 \\ 1 & a_5 & a_1 & a_2 & b_2 \\ 1 & a_4 & a_5 & a_1 & b_3 \\ 1 & a_3 & a_4 & a_5 & b_4 \end{vmatrix} + \begin{vmatrix} 1 & a_2 & a_3 & b_4 & a_5 \\ 1 & a_1 & a_2 & b_5 & a_4 \\ 1 & a_5 & a_1 & b_1 & a_3 \\ 1 & a_4 & a_5 & b_2 & a_2 \\ 1 & a_3 & a_4 & b_3 & a_1 \end{vmatrix} + \begin{vmatrix} 1 & a_2 & b_3 & a_4 & a_5 \\ 1 & a_1 & b_4 & a_3 & a_4 \\ 1 & a_5 & b_5 & a_2 & a_3 \\ 1 & a_4 & b_1 & a_1 & a_2 \\ 1 & a_3 & b_2 & a_5 & a_1 \end{vmatrix} + \begin{vmatrix} 1 & b_2 & a_3 & a_4 & a_5 \\ 1 & b_3 & a_2 & a_3 & a_4 \\ 1 & b_4 & a_1 & a_2 & a_3 \\ 1 & b_5 & a_5 & a_1 & a_2 \\ 1 & b_1 & a_4 & a_5 & a_1 \end{vmatrix}.$$

To effect the proof it would seem as if we had to show that the cofactors of b_1, b_2, b_3, b_4, b_5 vanish separately: but, as before, although the said five cofactors do vanish separately, it is sufficient only to show that one of them vanishes, say the cofactor of b_1 . Our problem is thus further reduced to proving the equality

$$0 = - \begin{vmatrix} 1 & a_2 & a_3 & a_4 \\ 1 & a_5 & a_1 & a_2 \\ 1 & a_4 & a_5 & a_1 \\ 1 & a_3 & a_4 & a_5 \end{vmatrix} - \begin{vmatrix} 1 & a_2 & a_3 & a_5 \\ 1 & a_1 & a_5 & a_4 \\ 1 & a_4 & a_5 & a_2 \\ 1 & a_3 & a_4 & a_1 \end{vmatrix} - \begin{vmatrix} 1 & a_2 & a_4 & a_5 \\ 1 & a_1 & a_3 & a_4 \\ 1 & a_5 & a_2 & a_3 \\ 1 & a_3 & a_5 & a_1 \end{vmatrix} - \begin{vmatrix} 1 & a_3 & a_4 & a_5 \\ 1 & a_2 & a_3 & a_4 \\ 1 & a_1 & a_2 & a_3 \\ 1 & a_5 & a_1 & a_2 \end{vmatrix};$$

and this is final, for the cofactors of the elements in the first columns, it will be found, cancel each other in pairs or in triads. As a matter of fact, if we call the four determinants P, Q, R, S, and append the suffixes 1, 2, 3, 4 to each to obtain a notation for the said cofactors, we have

$$\begin{aligned} -P_1 - Q_3 + R_2 &= 0 \\ P_2 - Q_1 &+ S_2 = 0 \\ P_4 &+ R_1 + S_4 = 0 \\ Q_4 - R_3 - S_1 &= 0 \\ -P_3 &+ R_4 = 0 \\ Q_2 &- S_3 = 0, \end{aligned}$$

where the vanishing trinomials are instances of a known theorem* regarding vanishing aggregates of secondary minors in a persymmetric determinant, the persymmetric determinant here being the circulant $C(a_1, a_2, a_3, a_4, a_5)$.

* Cazzaniga, T., 'Rendic. . . . Istituto Lombardo' (2), xxxi, pp. 610-614; Muir, T., 'Trans. R. Soc. Edin.', xxxix, p. 226; xl, pp. 511-533.

(3) In the foregoing analytic search for a proof the primary minors of the determinant

$$\begin{vmatrix} 1 & a_2 & a_3 & a_4 & a_5 \\ 1 & a_1 & a_2 & a_3 & a_4 \\ 1 & a_5 & a_1 & a_2 & a_3 \\ 1 & a_4 & a_5 & a_1 & a_2 \\ 1 & a_3 & a_4 & a_5 & a_1 \end{vmatrix}$$

will be found on closer investigation to play an important part. It is naturally viewable as the determinant got from the circulant $C(a_1, a_2, a_3, a_4, a_5)$ by removing the factor $a_1 + a_2 + a_3 + a_4 + a_5$, and it is what our determinants of §1 reduce to on making all the b 's vanish.

Two properties of the said minors have been made use of for our main purpose, but in their quite general forms they are worth enunciating on their own account. The first is that in the determinant $C(a_1, a_2, a_3, a_4, a_5) / (a_1 + a_2 + a_3 + a_4 + a_5)$ the cofactor of the $(r, s)^{th}$ element differs only in sign from the cofactor of the $(r + s - 1, 7 - s)^{th}$ element, (r, s) being any place in the secondary diagonal or on the upper side of it but not in the first column. The second is that in the determinant $C(a_1, a_2, a_3, a_4, a_5) / (a_1 + a_2 + a_3 + a_4 + a_5)$ we have

$$\text{cof}(r, 2) + \text{cof}(r + 1, 3) + \text{cof}(r + 2, 4) + \text{cof}(r + 3, 5) = 0,$$

where r may have any one of the values 1, 2, 3, 4, 5, and $\text{cof}(r, s)$ stands for the cofactor of the element in the $(r, s)^{th}$ place.

(4) Now let M denote the determinant of the sum of the matrices of

$$C(a_1, a_2, a_3, a_4, a_5), \quad C(b_1, b_2, b_3, b_4, b_5),$$

the former being taken symmetrical with respect to the secondary diagonal, and the latter with respect to the primary diagonal; and let N denote the determinant of the differences of the same two matrices. Then multiplying M by N in the ordinary way we find that only three of the twenty-five (25) products of pairs of rows are distinct, one occurring 5 times, and each of the two others 10 times. Further, we find that the product-determinant comes out in the form of a circulant, namely, that

$$\begin{aligned} MN \text{ i. e. } & \begin{vmatrix} a_1+b_1 & a_2+b_2 & \dots & a_5+b_5 \\ a_5+b_5 & a_1+b_1 & \dots & a_4+b_4 \\ a_4+b_4 & a_5+b_5 & \dots & a_3+b_3 \\ a_3+b_3 & a_4+b_4 & \dots & a_2+b_2 \\ a_2+b_2 & a_3+b_3 & \dots & a_1+b_1 \end{vmatrix} \cdot \begin{vmatrix} a_1-b_1 & a_2-b_2 & \dots & a_5-b_5 \\ a_5-b_5 & a_1-b_1 & \dots & a_4-b_4 \\ a_4-b_4 & a_5-b_5 & \dots & a_3-b_3 \\ a_3-b_3 & a_4-b_4 & \dots & a_2-b_2 \\ a_2-b_2 & a_3-b_3 & \dots & a_1-b_1 \end{vmatrix} \\ &= \begin{vmatrix} U & V & W & W & V \\ V & U & V & W & W \\ W & V & U & V & W \\ W & W & V & U & V \\ V & W & W & V & U \end{vmatrix} = C(U, V, W, W, V), \end{aligned}$$

where U, V, W stand for

$\Sigma a_1^2 - \Sigma b_1^2, \quad \Sigma a_1 a_2 - \Sigma b_1 b_2, \quad \Sigma a_1 a_3 - \Sigma b_1 b_3$
respectively.* In the next place, since it is readily verifiable that

$$(\Sigma a_1 + \Sigma b_1)(\Sigma a_1 - \Sigma b_1) = U + 2V + 2W,$$

we may strike out from the three determinants of the equality the factors $\Sigma a_1 + \Sigma b_1, \Sigma a_1 - \Sigma b_1, U + 2V + 2W$ respectively, thus arriving at

$$\frac{M}{\Sigma a_1 + \Sigma b_1} \cdot \frac{N}{\Sigma a_1 - \Sigma b_1} = \frac{C(U, V, W, W, V)}{U + 2V + 2W}$$

and therefore by using the result specified in §1, and by factorising $C(U, V, W, W, V)$ with the help of ϵ , an imaginary fifth root of 1, we obtain

$$\begin{aligned} \left(\frac{M}{\Sigma a_1 + \Sigma b_1} \right)^2 &= (U + V\epsilon + W\epsilon^2 + W\epsilon^3 + V\epsilon^4) \\ &\quad \cdot (U + V\epsilon^2 + W\epsilon^4 + W\epsilon + V\epsilon^3) \\ &\quad \cdot (U + V\epsilon^3 + W\epsilon + W\epsilon^4 + V\epsilon^2) \\ &\quad \cdot (U + V\epsilon^4 + W\epsilon^3 + W\epsilon^2 + V\epsilon) \\ &= \{U + V(\epsilon + \epsilon^4) + W(\epsilon^2 + \epsilon^3)\}^2 \\ &\quad \cdot \{U + V(\epsilon^2 + \epsilon^3) + W(\epsilon + \epsilon^4)\}^2 \end{aligned}$$

whence

$$\frac{M}{\Sigma a_1 + \Sigma b_1} = \{U + V(\epsilon + \epsilon^{-1}) + W(\epsilon^2 + \epsilon^{-2})\} \\ \cdot \{U + V(\epsilon^2 + \epsilon^{-2}) + W(\epsilon + \epsilon^{-1})\},$$

and so, finally, the interesting result regarding the resolution of M into factors, namely

$$\begin{aligned} &\begin{vmatrix} a_1 + b_1 & a_2 + b_2 & a_3 + b_3 & a_4 + b_4 & a_5 + b_5 \\ a_5 + b_2 & a_1 + b_3 & a_2 + b_4 & a_3 + b_5 & a_4 + b_1 \\ a_4 + b_3 & a_5 + b_4 & a_1 + b_5 & a_2 + b_1 & a_3 + b_2 \\ a_3 + b_4 & a_4 + b_5 & a_5 + b_1 & a_1 + b_2 & a_2 + b_3 \\ a_2 + b_5 & a_3 + b_1 & a_4 + b_2 & a_5 + b_3 & a_1 + b_4 \end{vmatrix} \\ &= (\Sigma a_1 + \Sigma b_1) \\ &\quad \cdot \left\{ (\Sigma a_1^2 - \Sigma b_1^2) + 2(\Sigma a_1 a_2 - \Sigma b_1 b_2) \cos \frac{2\pi}{5} + 2(\Sigma a_1 a_3 - \Sigma b_1 b_3) \cos \frac{4\pi}{5} \right\} \\ &\quad \cdot \left\{ (\Sigma a_1^2 - \Sigma b_1^2) + 2(\Sigma a_1 a_2 - \Sigma b_1 b_2) \cos \frac{4\pi}{5} + 2(\Sigma a_1 a_3 - \Sigma b_1 b_3) \cos \frac{2\pi}{5} \right\} \end{aligned}$$

the generalisation of which for any order is enunciated in the 'Messenger of Math.,' xi, pp. 105-108.

* Σ is used as the symbol of a cyclic sum, for example, $\Sigma a_1 a_2 = a_1 a_2 + a_2 a_3 + a_3 a_4 + a_4 a_1 + a_5 a_2$.

MAGNETIC OBSERVATIONS IN RHODESIA.

By THE REV. E. GOETZ, S.J., M.A., F.R.S.S.Afr.

The observations recorded in this paper were taken in 1914 and 1916 with the unifilar magnetometer, Nalder Bros. 135, and the Dover Circle 113. The observations are given without corrections as the corrections to these instruments have not been determined. In the reduction of the observations the constants determined at Kew in 1898 have been used throughout except in the case of the Moment of Inertia of the Collimator Magnet, of which the suspension apparatus had undergone some change in weight. A new value for the moment was determined in the course of the observations. For this three sets of determinations, each consisting of two sets of vibrations with loaded magnet enclosing a set with unloaded magnet, were taken.

The three values for $\log. \pi^2 K$ were 3.38807, 3.38825, 3.38753, the mean of which, 3.38785, has been adopted for the determination of the magnetic moment.

The Distribution Coefficient has been deduced separately for the 1914 and 1916 observations.

In the Barotseland Expedition the astronomical observations were taken and reduced by Mr. H. E. Wood, Chief Assistant of the Union Observatory. Time, latitude and longitude were determined by both sun and star series, and may be considered as very reliable, especially as three chronometers were used for the longitude determinations.

In the Matabeleland Expedition, I took the time and latitude with a Claude prismatic astrolabe. The results for both were highly satisfactory, considering the difficulty of observations at night by one observer alone in the South African Veldt.

The latitudes give a probable error of 1".1 and the time observations an error of 0.18. As I had only one chronometer with me I give the longitudes to the nearest tenth of a minute only. These have been besides checked by reference to the Surveyor General's map, the scale of which is of one inch to four miles.

In the Barotseland Expedition I took only one set of magnetic observations as we were rather pressed for time. A hitch in the transport arrangements gave me an opportunity of taking a set of declination readings at every quarter of an hour throughout a whole day at Katombora.

In the Matabeleland Expedition I took two or three declinations at different times and a set of deflections between two sets of vibrations at each station.

I am indebted to the Royal Society of South Africa and to the Rhodesia Scientific Association for Research grants in connection with this survey, and to the British South Africa Company for the river transport on the Zambesi. It is owing to these generous contributions that I have been able to carry on this survey over a line covering 1000 miles in practically unoccupied lands.

STATIONS IN BAROTSELAND, NORTHERN RHODESIA.

1. KATOMBORA.—Lat. $12^{\circ} 48' 7''$ S.; long. $25^{\circ} 21' 5''$ E. On the left bank of the Zambesi, just above the rapids, about 50 yards from the river.
2. LEALUI.—Lat. $15^{\circ} 14' 6''$ S.; long. $24^{\circ} 00' 4''$ E. On the left bank of the Zambesi, on the left bank of the Zambesi-Lealui canal, about a quarter of a mile from the native town.
3. LIWALI.—Lat. $16^{\circ} 20' 2''$ S.; long. $23^{\circ} 17' 2''$ E. On the Matabele Flats, on the right bank of the Zambesi opposite the mouth of the Kakinje river.
4. MAGONDA.—Lat. $17^{\circ} 30' 3''$ S.; long. $24^{\circ} 40' 5''$ E. Large island of the Zambesi, about 12 miles up the river from Sesheke. Station on the side facing the Caprivi Strip, about one-third from the lower end of the island.
5. MUKWANGA.—Lat. $16^{\circ} 58' 4''$ S.; long. $23^{\circ} 56' 5''$ E. Small island of the Zambesi, between the M'Bombwe and Luso rapids.
6. MUNDALE.—Lat. $15^{\circ} 44' 6''$ S.; long. $23^{\circ} 11' 1''$ E. On the left bank of the Zambesi, a few yards from the river.
7. NALISA.—Lat. $17^{\circ} 22' 9''$ S.; long. $24^{\circ} 19' 3''$ E. Below the Katama-Molilo Rapids, on the left bank of the Zambesi, about 50 yards from the river.
8. NALOLO.—Lat. $15^{\circ} 31' 8''$ S.; long. $23^{\circ} 07' 3''$ E. At the Native Commissioner's residence, about 100 yards in front of the house.
9. NGAMBWE RAPIDS.—Lat. $17^{\circ} 16' 2''$ S.; long. $24^{\circ} 09' 3''$ E. At the foot of the rapids, on the left bank of the Zambesi, near the southern end of the portage cutting.
10. SESHEKE.—Lat. $17^{\circ} 30' 0''$ S.; long. $24^{\circ} 52' 0''$ E. About 100 yards from the western side of the Magistrate's residence.
11. SENANGA.—Lat. $16^{\circ} 02' 5''$ S.; long. $23^{\circ} 15' 2''$ E. On a creek of the Zambesi, at the foot of the rise to the Native Labour Bureau.
12. SIOMA (GONYE FALLS).—Lat. $16^{\circ} 40' 2''$ S.; long. $23^{\circ} 35' 0''$ E. On the left bank of the Zambesi, at the northern end of the portage road, near the junction of the river and the Sioma Canal.
13. UMGWEZI RIVER.—Lat. $17^{\circ} 39' 1''$ S.; long. $25^{\circ} 05' 7''$ E. About 100 yards from the left banks of the Zambesi and the Umgwezi.
14. X.—Lat. $17^{\circ} 36' 1''$ S.; long. $25^{\circ} 04' 5''$ E. On the right bank of the Zambesi, about three miles up the river from the mouth of the Umgwezi.

STATIONS IN MATABELELAND, SOUTHERN RHODESIA.

1. ANTELOPE MINE.—Lat. $21^{\circ} 02' 14''$ S.; long. $28^{\circ} 26' 5''$ E. On the right bank of the Shashani, about 300 yards north of the drift.
2. EMPANDENI MISSION.—Lat. $20^{\circ} 42' 28''$ S.; long. $27^{\circ} 53' 2''$ E. Back of the mission house, 100 yards from the south-east corner.
3. FORT MANGWE.—Lat. $20^{\circ} 43' 29''$ S.; long. $28^{\circ} 02' 7''$ E. About 100 yards north-west of the old fort.
4. FORT USHER.—Lat. $20^{\circ} 24' 25''$ S.; long. $28^{\circ} 35' 3''$ E. Near the rocks back of the Native Commissioner's residence. In 1905 the observations were taken at the place now occupied by the Commissioner's offices.
5. JIM.—Lat. $20^{\circ} 54' 22''$ S.; long. $28^{\circ} 07' 5''$ E. On the farm Jim at the foot of the kopje, midway between the homestead and the river.
6. MABULI RIVER.—Lat. $29^{\circ} 49' 08''$ S.; long. $28^{\circ} 29' 2''$ E. On the right bank 200 yards from the river and 200 yards east of the Antelope Road.
7. MARULA.—Lat. $20^{\circ} 28' 25''$ S.; long. $28^{\circ} 05' 2''$ E. At the railway station 500 yards down the line and 500 yards on the right of the line (looking south).
8. MATOPOS (AMERICAN MISSION).—Lat. $20^{\circ} 26' 16''$ S.; long. $28^{\circ} 42' 3''$ E. About 300 yards back of the mission house.
9. OVE RIVER.—Lat. $20^{\circ} 40' 47''$ S.; long. $28^{\circ} 30' 6''$ E. On the Antelope-Bulawayo road, at the entrance to the hills, 200 yards west of the road.
10. SELOSI MISSION.—Lat. $20^{\circ} 11' 25''$ S.; long. $28^{\circ} 09' 6''$ E. West of the mission about 500 yards.
11. WHITE WATER (MATOPOS).—Lat. $20^{\circ} 32' 05''$ S.; long. $28^{\circ} 28' 9''$ E. Outspan on the Antelope-Bulawayo road, about half-way through the hills.

BAROTSELAND STATIONS.

Declination *D.* Katombora, July 28th, 1914.

| G.M.T. | D. | G.M.T. | D. |
|-----------|-------------------------|------------|-------------------------|
| 7.13 a.m. | $16^{\circ} 50' 6''$ W. | 11.35 a.m. | $16^{\circ} 48' 2''$ W. |
| 7.35 " | $16^{\circ} 51' 5''$ " | 11.35 " | $16^{\circ} 47' 2''$ " |
| 7.50 " | $16^{\circ} 51' 6''$ " | 12.05 p.m. | $16^{\circ} 46' 6''$ " |
| 8.05 " | $16^{\circ} 51' 6''$ " | 12.20 " | $16^{\circ} 46' 6''$ " |
| 8.20 " | $16^{\circ} 51' 4''$ " | 12.35 " | $16^{\circ} 45' 4''$ " |
| 8.35 " | $16^{\circ} 51' 7''$ " | 12.50 " | $16^{\circ} 45' 5''$ " |
| 8.50 " | $16^{\circ} 51' 5''$ " | 1.05 " | $16^{\circ} 44' 2''$ " |
| 9.05 " | $16^{\circ} 51' 4''$ " | 1.20 " | $16^{\circ} 44' 1''$ " |
| 9.20 " | $16^{\circ} 51' 1''$ " | 1.35 " | $16^{\circ} 44' 4''$ " |
| 9.35 " | $16^{\circ} 51' 1''$ " | 1.50 " | $16^{\circ} 44' 0''$ " |
| 9.50 " | $16^{\circ} 50' 8''$ " | 2.05 " | $16^{\circ} 43' 0''$ " |
| 10.05 " | $16^{\circ} 50' 3''$ " | 2.20 " | $16^{\circ} 43' 0''$ " |
| 10.20 " | $16^{\circ} 50' 0''$ " | 2.35 " | $16^{\circ} 42' 5''$ " |
| 10.35 " | $16^{\circ} 50' 1''$ " | 2.50 " | $16^{\circ} 43' 6''$ " |
| 10.50 " | $16^{\circ} 49' 6''$ " | 3.05 " | $16^{\circ} 44' 1''$ " |
| 11.05 " | $16^{\circ} 49' 9''$ " | 3.20 " | $16^{\circ} 45' 3''$ " |
| 11.20 " | $16^{\circ} 48' 7''$ " | 3.55 " | $16^{\circ} 44' 5''$ " |

Mean declination $16^{\circ} 48' 1''$ at 11.30 a.m. G.M.T.

| Station | Date, 1914. | G.M.T. | D. West. |
|-----------------|-----------------|----------------|-----------|
| Katombora . . . | July 27 . . . | 8.00 a.m. . . | 16° 51' 1 |
| Lealui . . . | { " 5 . . . | 2.43 p.m. . . | 15° 42' 9 |
| | " 6 . . . | 8.16 a.m. . . | 15° 49' 4 |
| Liwali . . . | " 13 . . . | 8.56 " . . . | 16° 13' 7 |
| Magonda . . . | " 22 . . . | 8.36 " . . . | 16° 16' 9 |
| Mukwanga . . . | " 17 . . . | 9.41 " . . . | 16° 48' 3 |
| Mundale . . . | " 10 . . . | 7.47 " . . . | 15° 37' 3 |
| Nalisa . . . | { " 17 . . . | 8.46 " . . . | 16° 36' 3 |
| | " 17 . . . | 10.21 " . . . | 16° 32' 6 |
| Nalolo . . . | " 8 . . . | 1.40 p.m. . . | 16° 08' 1 |
| Ngambwe . . . | " 19 . . . | 8.14 a.m. . . | 16° 59' 9 |
| Senanga . . . | June 28 . . . | 12.44 p.m. . . | 15° 50' 6 |
| Sesheke . . . | " 13 . . . | 10.21 a.m. . . | 16° 35' 1 |
| Sioma . . . | July 15 . . . | 9.30 " . . . | 16° 06' 6 |
| Umgwezi . . . | " 24 . . . | 10.00 " . . . | 16° 21' 2 |
| X . . . | { June 10 . . . | 8.14 " . . . | 16° 40' 4 |
| | | 10.28 " . . . | 16° 40' 1 |
| | | 11.20 " . . . | 16° 39' 4 |

Inclination I. South.

| Station. | Date, 1914. | G.M.T.* | Needles. | Mean I. South. |
|-----------------|-----------------|------------|--|----------------|
| Katombora . . . | July 27 . . . | 12.44 p.m. | { N ₂ 51° 39' 8 N ₃ 51° 40' 6 } | . 51° 40' 2 |
| Lealui . . . | " 6 . . . | 1.43 " | { N ₂ 48° 15' 3 N ₃ 48° 12' 6 } | . 48° 14' 0 |
| Liwali . . . | " 13 . . . | 10.46 a.m. | { N ₂ 49° 50' 5 N ₃ 49° 48' 3 } | . 49° 49' 4 |
| Magonda . . . | " 22 . . . | 10.16 " | { N ₂ 51° 14' 9 N ₃ 51° 15' 1 } | . 51° 15' 0 |
| Mukwanga . . . | " 17 . . . | 11.11 " | { N ₂ 50° 25' 9 N ₃ 50° 27' 1 } | . 50° 26' 5 |
| Mundale . . . | " 10 . . . | 11.30 " | { N ₂ 49° 17' 7 N ₃ 49° 26' 5 } | . 49° 22' 1 |
| Nalisa . . . | { June 16 . . . | 2.53 p.m. | { N ₂ 51° 18' 4 N ₃ 51° 23' 3 } | . 51° 20' 8 |
| | " 17 . . . | 12.09 " | { N ₂ 51° 18' 2 N ₃ 51° 14' 2 } | . 51° 16' 2 |
| Nalolo . . . | July 8 . . . | 4.34 " | { N ₂ 48° 38' 7 N ₃ 48° 31' 7 } | . 48° 35' 2 |
| Ngambwe . . . | " 19 . . . | 10.40 a.m. | { N ₂ 50° 46' 8 N ₃ 50° 51' 4 } | . 50° 49' 1 |
| Senanga . . . | June 28 . . . | 2.28 p.m. | { N ₂ 49° 54' 2 N ₃ 49° 59' 2 } | . 49° 56' 7 |
| Sesheke . . . | " 13 . . . | 6.56 a.m. | { N ₂ 51° 05' 7 N ₃ 51° 09' 3 } | . 51° 07' 5 |
| Sioma . . . | July 15 . . . | 10.45 " | { N ₂ 49° 46' 8 N ₃ 49° 49' 9 } | . 49° 48' 4 |
| Umgwezi . . . | " 24 . . . | 11.22 " | { N ₂ 51° 31' 6 N ₃ 51° 28' 3 } | . 51° 30' 0 |

* Note G.M.T. for the mean of the two needles.

Intensity *H*.

| Station. | Date, 1914. | G.M.T. | H ₂₀ | H ₄₀ | H. |
|-----------|-------------|-----------|-----------------|-----------------|-------|
| Katombora | July 27 | 9.46 a.m. | 21485 | 21489 | 21487 |
| Lealui | " 6 | 11.07 " | 22836 | 22840 | 22838 |
| Liwali | " 13 | 8.24 " | 22252 | 22267 | 22259 |
| Magonda | " 22 | 8.12 " | 21723 | 21699 | 21711 |
| Mukwanga | " 17 | 8.35 " | 21932 | 21930 | 21931 |
| Mundale | " 10 | 8.48 " | 22762 | 22763 | 22762 |
| Nalisa | June 17 | 10.22 " | 21650 | 21654 | 21652 |
| Nalolo | July 8 | 3.00 p.m. | 22713 | 22700 | 22706 |
| Ngambwe | " 19 | 8.04 a.m. | 21838 | 21842 | 21840 |
| Senanga | June 28 | 10.25 " | 21885 | 21870 | 21877 |
| Sesheke | " 13 | 1.18 p.m. | 21806 | 21810 | 21808 |
| Sioma | July 15 | 8.20 a.m. | 22086 | 22095 | 22090 |
| Umgwezi | " 24 | 9.15 " | 21589 | 21605 | 21597 |
| X | June 10 | 1.33 p.m. | 21688 | 21674 | 21681 |

MATABELELAND STATIONS.

Declination *D*. West.

| Station. | Date. | G.M.T. | Obs. D. | Mean D. West. |
|-------------|---|--|--|--------------------------|
| Antelope | July 28, 1916 | { 10.00 a.m. . 3.04 p.m. . | { 16° 37' 2 . 16° 37' 3 . | { 16° 37' 3 |
| Empandeni | " 14, 1916 | { 10.17 a.m. . 11.35 " . 3.40 p.m. . | { 16° 32' 1 . 16° 30' 1 . 16° 30' 8 . | { 16° 31' 0 |
| Ft. Mangwe | " 16, 1916 | { 11.25 a.m. . 2.27 p.m. . | { 16° 26' 0 . 16° 23' 1 . | { 16° 24' 5 |
| Ft. Usher | { Aug. 5, 1916 . May 9, 1905 . " 10, 1905 . | { 8.52 a.m. . 12.48 p.m. . 3.36 " . 7.34 a.m. . | { 16° 13' 8 . 16° 07' 4 . 18° 49' 5 . 18° 44' 7 . | { 16° 10' 6 18° 47' 1 |
| Jim | July 18, 1916 | { 11.31 " . 12.11 p.m. . 2.58 " . | { 16° 59' 6 . 16° 57' 9 . 16° 57' 8 . | { 16° 58' 4 |
| Mabuli | " 30, 1916 | { 10.38 a.m. . 2.21 p.m. . | { 16° 28' 8 . 16° 29' 2 . | { 16° 29' 0 |
| Marula | " 10, 1916 | { 9.00 a.m. . 2.50 p.m. . | { 16° 26' 1 . 16° 21' 9 . | { 16° 24' 0 |
| Matopos | May 11, 1905 | 7.55 a.m. | 18° 31' 3 | 18° 31' 3 |
| Ove | July 31, 1916 | { 8.31 " . 9.19 " . 11.08 " . | { 16° 20' 4 . 16° 18' 4 . 16° 09' 1 . | { 16° 16' 0 |
| Selosi | " 7, 1916 | { 9.33 " . 12.01 p.m. . 4.19 " . | { 16° 21' 3 . 16° 22' 7 . 16° 25' 6 . | { 16° 23' 2 |
| White Water | Aug. 2, 1916 | { 11.29 a.m. . 12.56 p.m. . 2.56 " . | { 16° 18' 2 . 16° 20' 3 . 16° 20' 8 . | { 16° 19' 8 |

Inclination I. South.

| Station. | Date. | G.M.T.* | Needles. | Mean I. South. |
|-------------|---------------|-----------|--|--------------------------|
| Antelope. | July 29, 1916 | 9.10 a.m. | $\left\{ \begin{array}{l} N_2 \ 55^\circ \ 29' \cdot 9 \\ N_3 \ 55^\circ \ 34' \cdot 0 \end{array} \right\}$ | $55^\circ \ 32' \cdot 0$ |
| Empandeni | " 15, 1916 | 7.10 " | $\left\{ \begin{array}{l} N_2 \ 55^\circ \ 03' \cdot 0 \\ N_3 \ 55^\circ \ 08' \cdot 4 \end{array} \right\}$ | $55^\circ \ 05' \cdot 7$ |
| Ft. Mangwe | " 16, 1916 | 9.10 " | $\left\{ \begin{array}{l} N_2 \ 55^\circ \ 04' \cdot 1 \\ N_3 \ 55^\circ \ 04' \cdot 0 \end{array} \right\}$ | $55^\circ \ 04' \cdot 1$ |
| Ft. Usher | Aug. 5, 1916 | 2.04 p.m. | $\left\{ \begin{array}{l} N_2 \ 55^\circ \ 15' \cdot 8 \\ N_3 \ 55^\circ \ 19' \cdot 5 \end{array} \right\}$ | $55^\circ \ 17' \cdot 7$ |
| | May 9, 1905 | 2.47 " | $\left\{ \begin{array}{l} N_2 \ 54^\circ \ 18' \cdot 1 \\ N_3 \ 54^\circ \ 20' \cdot 2 \end{array} \right\}$ | $54^\circ \ 19' \cdot 1$ |
| Jim. | July 18, 1916 | 9.03 a.m. | $\left\{ \begin{array}{l} N_2 \ 55^\circ \ 32' \cdot 0 \\ N_3 \ 55^\circ \ 30' \cdot 8 \end{array} \right\}$ | $55^\circ \ 31' \cdot 4$ |
| Mabuli | " 30, 1916 | 3.04 p.m. | $\left\{ \begin{array}{l} N_2 \ 55^\circ \ 02' \cdot 5 \\ N_3 \ 55^\circ \ 07' \cdot 4 \end{array} \right\}$ | $55^\circ \ 04' \cdot 9$ |
| Marula | " 10, 1916 | 3.40 " | $\left\{ \begin{array}{l} N_2 \ 55^\circ \ 02' \cdot 0 \\ N_3 \ 54^\circ \ 54' \cdot 3 \end{array} \right\}$ | $54^\circ \ 53' \cdot 1$ |
| Matopos | May 11, 1905 | 1.23 " | $\left\{ \begin{array}{l} N_2 \ 54^\circ \ 22' \cdot 6 \\ N_3 \ 54^\circ \ 12' \cdot 0 \end{array} \right\}$ | $54^\circ \ 17' \cdot 3$ |
| Ove. | July 31, 1916 | 3.14 " | $\left\{ \begin{array}{l} N_2 \ 55^\circ \ 10' \cdot 9 \\ N_3 \ 55^\circ \ 16' \cdot 8 \end{array} \right\}$ | $55^\circ \ 13' \cdot 8$ |
| Selosi | " 8, 1916 | 8.38 a.m. | $\left\{ \begin{array}{l} N_2 \ 54^\circ \ 54' \cdot 3 \\ N_3 \ 55^\circ \ 00' \cdot 2 \end{array} \right\}$ | $54^\circ \ 57' \cdot 3$ |
| White Water | Aug. 2, 1916 | 9.16 " | $\left\{ \begin{array}{l} N_2 \ 55^\circ \ 16' \cdot 7 \\ N_3 \ 55^\circ \ 22' \cdot 0 \end{array} \right\}$ | $55^\circ \ 19' \cdot 4$ |

* Note G.M.T. for the mean of the two needles.

Intensity H.

| Station. | Date, 1916. | G.M.T. | H ₃₀ | H ₄₀ | H |
|-------------|-------------|------------|-----------------|-----------------|--------|
| Antelope | July 29 | 12.52 p.m. | ·20057 | ·20059 | ·20058 |
| Empandeni | " 15 | 1.46 " | ·20137 | ·20151 | ·20144 |
| Ft. Mangwe | " 16 | 1.03 " | ·20189 | ·20189 | ·20189 |
| Ft. Usher | Aug. 5 | 10.42 a.m. | ·20278 | ·20263 | ·20271 |
| Jim | July 18 | 1.21 p.m. | ·19844 | ·19830 | ·19837 |
| Mabuli | " 30 | 12.33 " | ·20499 | ·20519 | ·20509 |
| Marula | " 10 | 2.51 " | ·20123 | ·20131 | ·20127 |
| Ove | " 31 | 10.32 a.m. | ·20197 | ·20180 | ·20188 |
| Selosi | " 8 | 3.18 p.m. | ·20375 | — | ·20375 |
| White Water | Aug. 2 | 1.55 " | ·20112 | ·20112 | ·20112 |

COLOUR AND CHEMICAL CONSTITUTION.

PART X.—A GENERAL NUMERICAL SOLUTION OF THE COLOUR-
CONSTITUTION PROBLEM.

BY JAMES MOIR.

In Part IX of this work it was shown that the spectra and colours of a particular class of triphenylcarbinol colours (viz. halogenated phthaleins) could be calculated from the data of a parent-substance by multiplying by a factor dependent on the nature, number and position of the substituents.

I have now discovered that this principle can be applied to all the ordinary triphenylcarbinol dyes ("aniline dyes"), the colours of which can now be calculated, as will be seen below.

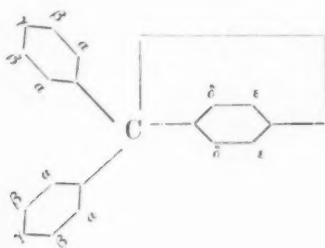
It has been shown in earlier parts of this work that the colour-phenomenon is additive, *i. e.* that each group present acts in colour-change almost independently of other groups and of the rest of the molecule.

I now find that each combination of group and position, *e. g.*, orthomethyl, parahydroxyl, etc., can be assigned a colour-factor by means of which the effect on colour of the substitution of the group for hydrogen in the given position can be calculated: even if five or six groups are present it is found that by multiplying the wave-length of the parent substance by all the factors of the groups present in a coloured substance a result is obtained which tallies closely with observation.

The apparent inconsistency between the new factorial notion and the "additive" notion is merely accidental. It is a well-known fact in mathematics that $(1 + a)(1 - b) = 1 + a - b$ without serious error unless a or b is more than $\frac{1}{10}$ or so. The "factors" are of the form $1 + a$ or $1 - b$ and the "additive" notion corresponds to the right side of the equation.

The parent-substance taken is an imaginary one,* being the anhydride of triphenylcarbinol or *p*-phenylenediphenylmethane:

* Said, however, to have been made; see Beilstein, ii, p. 292.



It would have been convenient to call this "chromane," but unfortunately Kostanecki has used this name already to denote the anhydride of *o*-oxy-phenylpropylalcohol. I shall therefore name it provisionally "fuchsene," which will indicate that it is the hydrocarbon of fuchsonine.

Its fundamental wave-length is found by multiplying that of benzaurine (its di-oxy-derivative) by the square of the ratio of the wave-lengths of benzaurine and aurine (tri-oxy-derivative), *i. e.* $x = 553^3 \div 534^2 = 593$.

The ratio $\frac{\text{aurine}}{\text{benzaurine}}$ is the first of my colour-factors, and is the para (or γ) hydroxyl-factor, its value being 0.9657; and it is to be noted that it is assumed to be the same whether $-\text{OH}$ replaces $-\text{H}$ or $:\text{O}$ is attached to fuchsene giving fuchsonine. The theoretical wave-length of fuchsonine (oxofuchsene or keto-fuchsene) if it were soluble in alkali would thus be $\lambda 593 \times 0.9657$ or $\lambda 572\frac{1}{2}$; that of oxyfuchsonine or benzaurine* (oxyoxofuchsene) is $\lambda 593 \times (0.9657)^2$ or $\lambda 553$; that of aurine (dioxyfuchsonine or dioxyoxofuchsene) is $\lambda 593 \times (0.9657)^3$ or $\lambda 534$.

The next ratio is the para (or γ) amino-factor, the value of which is 0.972. The calculated wave-length for "fuchsonimine"† (iminofuchsene) is $\lambda 593 \times 0.972$ or $\lambda 576$, but $\lambda 430$ was observed in alcohol, with two other bands (ratio 16:13:10), which is certainly abnormal, but if the series is really 22:19:16:13:10 the observed band, which would be about $\lambda 425$ in water, agrees well with $\frac{16}{22} \times 576$.

The calculated wave-length for the diamino-derivative, which is the well-known Doebner's violet, is $\lambda 593 \times (0.972)^2$ or $\lambda 560\frac{1}{2}$. The reading $\lambda 565$ in alcohol is on record, and it is to be noted that there is no ionisation in alcohol, so that the chlorine of the coloured salt counts as part of the

* There appear to be two kinds of benzaurine. The one in the text, of $\lambda 553$, is made from *p*-oxybenzophenone and phenol, the other of $\lambda 570$ (Part I, 1917, p. 6) from benzaldehyde and phenol with oxidation. These two reactions should give the same product, but the products are undoubtedly different.

† This confusing name should be changed to fuchsimine.

molecule. From the analogy of the behaviour of fuchsine I should estimate that the ion of Doebner's violet in water would have λ about 560. My own preparation has λ 562. The calculated wave-length for the triamino-derivative of fuchsene, which is the ordinary dye parafuchsine, is λ 593 \times (0.972)³ or λ 544. This agrees with direct observation in water.

These two ratios can next be combined. The theoretical wave-length for oxyfuchsonimine or aminofuchsone is λ 593 \times 0.9657 \times 0.972 or λ 556½. Observed λ 558. That for diaminofuchsone is λ 593 \times 0.9657 \times (0.972)² or λ 541. Observed λ 541. That for dioxyfuchsonimine is λ 593 \times (0.9657)² \times 0.972 or λ 537½. I have made this new substance, which is alternatively named paramino-benzaurine, and observed its wave-length to be λ 538.

The third ratio is the N-methyl-factor, which has the value 1.0245. From this the colours of all the violet and green dyes of the series can be calculated. It will be found more convenient, however, to combine the second and third factors, giving (fourthly) a γ -N-methylamino-factor, the value of which is practically unity (viz. 0.9965), and (fifthly) a γ -N-dimethylamino-factor, the value of which is 1.021.

Applying these, the theoretical colour of "fuchsonedimethylimine" (dimethylaminofuchsene) is λ 593 \times 1.021 or λ 605½. The only band, in water, of this substance is very broad, at about λ 460, and may be a harmonic, since $\frac{3}{4}$ of 605½ is 454. The fraction $\frac{3}{4}$ agrees exactly: see previous page.

That of bis-dimethylaminofuchsene ("malachite green") is λ 593 \times (1.021)² or λ 619, agreeing with observation. That of *tris-dimethylaminofuchsene ("crystal-violet") is calculated to be λ 593 \times (1.021)³ or λ 632. This agrees with observation in the green phase of crystal violet obtained by adding a trace of mineral acid to its solution (observed λ 632, but in neutral solution λ 595).† Hofmann's violet (pentamethylpararosaniline) is calculated to have wave-length λ 593 \times (1.021)² \times 0.9965 or λ 616; this also agrees with the acid phase of this dye. It is to be noted that the commercial article is partly derived from orthotoluidine (methylated fuchsine or rosaniline, not parafuchsine) and therefore gives colours a shade higher up the scale.

I have also made the remaining new member of this series, dimethylaminofuchsone (dimethylamino-oxofuchsene), by condensing paraoxybenzophenone with dimethylaniline and AlCl₃. This has a wave-length of λ 586 when neutral (violet, sparingly soluble), but develops a pink colour and two other bands, λ 500 and 530, when acid (isomers?). The calculated colour is λ 593 \times 1.021 \times 0.9657 or λ 585. Another member of the series is "paraoxy-malachite-green," which is bis-dimethylaminofuchsone. Its calculated colour is that of the foregoing multiplied by 1.021 or λ 597, which agrees with its

* The correct Latin for thrice is *ter* but might be unintelligible.

† The violet phase is discussed later on.

described colour. My preliminary observations indicate that the band varies between λ 580 and λ 607 according to the reaction of the solution.

Perhaps it is surprising that even "iodine-green" (heptamethylparosaniline, with three methyls on one nitrogen) agrees with theory, as far as can be seen. The value of λ should be $593 \times (0.972)^3 \times (1.0245)^7$ or 645. The band observed in a commercial specimen was λ 640.

Another important point is that the effect of N-ethyl is scarcely distinguishable from that of N-methyl—the value of (6) the γ -N-diethyl-amino-factor being about 1.023 as against 1.021 for dimethylamino.

A factor for the replacement of $-\text{OH}$ by $-\text{NEt}_2$ can be calculated from the foregoing data. The process of replacing $\gamma\text{-OH}$ by $\gamma\text{-H}$ has the factor $1 \div 0.9657$, and the factor for replacing $\gamma\text{-H}$ by $\gamma\text{-NEt}_2$ is 1.023; hence the required factor is $1.023 \div 0.9657$ or 1.061. Applying this to the case of fluorescein and rhodamine, we here use the factor with a different constant, viz. that of fluorescein, λ 494. The replacement of two hydroxyl by two diethylamino-groups should give a substance with wave-length $494 \times (1.061)^2$ or 555. Observation on commercial rhodamine gave λ 556.

Correlation of the Phthaleins with the Aniline Dyes.—We now introduce a seventh factor, namely that of the orthocarboxyl group present in the phthaleins. This factor is very close to unity, being equal to 1.002. As examples benzaurine of λ 553 may be compared with phenolphthalein λ 554, and $\beta\beta'$ -tetra-bromobenzaurine of λ 583 with tetrabromophenolphthalein of λ 584 $\frac{1}{2}$. It will be sufficient at this stage to calculate only one or two of the observed colours. Phenoldimethylanilinephthalein (see Part II, p. 112) is the oxy-dimethylamino-carboxylic acid of fuchsene, and its calculated wave-length is $593 \times 0.9657 \times 1.021 \times 1.002$ or 587, and that was also the reading observed in the alkaline solution of this substance.

Curiously enough, bis-dimethylanilinephthalein appears to be colourless. Its wave-length should be 622, as it is the carboxylic acid of malachite-green. The sulphophthalein, however, is not colourless, but has λ 634 or λ 593 according as it is acid or neutral.

At this stage the other factors for substitution in phenolphthalein may be combined with the parahydroxy-factor so as to express the compounds investigated in Parts I to VI (see the summary on the last page of Part IV) as direct derivatives of fuchsene. The ratio of phenolphthalein to fuchsene is 0.934. Now since the value of (8) the ortho- (or ϵ -) bromine atom-factor is 1.0133 in phenolphthalein, the lengthy calculation of ϵ -tetrabromophenolphthalein from first principles as $593 \times (0.9657)^2 \times 1.002 \times (1.0133)^4$ may be shortened to $593 \times 0.934 \times (1.0133)^4$, both coming to λ 584, and agreeing with observation.

We may again repeat here the remarkable circumstance that methyl, ethyl, isopropyl, chlorine, bromine, and iodine in the ϵ -positions have all

nearly the same effect on colour, their colour-factors being 1.013 ± 0.001 (9th to 13th of the known factors); also that in the δ position the effect is twice as great, the colour-factor being $1.025 \pm .002$.

Before finishing with the phthaleins it may be noted that the behaviour of the para-position in the phthalic ring both of phenolphthalein and of fluorescein is usually abnormal—a point which is discussed in a separate communication. Another exception is oxydiphenylphthalide, which being fuchsoncarboxylic acid should have λ 574, whereas observation gave λ 560. It is very difficult to obtain this substance free from phenolphthalein, and it is excessively easily bleached by alkali, so much so that the American writers on colour describe it as colourless in alkali.

The 14th colour-factor, that of γ -methoxyl, depends on two observations only, and is therefore somewhat in doubt: its value is 0.973. This makes the γ -CH₃ in phenolphthalein-monomethylether have a factor value of 1.007, whereas the ϵ -CH₃* has, as mentioned just above, the value 1.012. The α -CH₃ and the δ -CH₃ both appear to have a value about 1.024, which is practically the same as the N-CH₃ given at the beginning (1.0245), so need not be counted as a new factor.

The 15th and 16th colour-factors are those of ϵ -hydroxyl and ϵ -methoxyl: their values are comparatively large, viz. 1.030 and 1.037 respectively. It is very significant that ϵ -OH and γ -OH are practically the reverse of one another ($1.030 \times 0.9657 = 0.9946$). An example of this is the substance catechaurine (β_3 -trioxaurine), made by condensing catechol with oxalic acid. The systematic name is β_3 - γ_3 -hexaoxyfuchsen, and its theoretical absorption is therefore $593 \times (0.9946)^3$ or $583\frac{1}{2}$, which agrees with observation (in dilute NaHCO₃ solution). It should be noted, however, that these polyhydroxyl-compounds from catechol are capable of exhibiting a second colour when dissolved in excess of NaOH. This is always a very high colour, generally green, and the colour-factor is then about 1.085 for the ϵ or β hydroxyl—really the ϵ or β ionised oxygen O'. For example, di-catechol-phthalein in NaOH shows λ 652 for its absorption-band, and by theory $593 \times (0.9657)^2 \times (1.085)^2 \times 1.002 = \lambda$ 653.

It should also be noted that when guaiacol combines to a phthalein or aurine, it is probable from the evidence stated in Part IV that the —OCH₃ group is *para*- and the —OH group *meta*- to the centre instead of *vice versa*. If then the 16th colour-factor just mentioned as being equal to 1.037 and derived from these guaiacol compounds is not ϵ -methoxyl in presence of γ -hydroxyl but γ -methoxyl accompanied by β - (or ϵ -) hydroxyl, the value of that combination, previously ascertained, should agree with $1.037 \times \gamma$ -hydroxyl. Now γ -OH is 0.9657, β -OH is 1.030, and γ -OCH₃ is about 0.973. Combining these we find $1.030 \times 0.973 = 1.003$ and 1.037×0.9657

* The distinction between the positions β and ϵ is only valid when γ is not occupied by OH, and does not exist in aurine compounds.

= 1.003. This practically proves that in the guaiacol colours the methyl is really *para* to the central carbon-atom: it is worth noting, however, that in this formulation of guaiacol-phthalein the compound becomes a meta-quinone, a type of compound which has hitherto met with no acceptance.

The 17th colour-factor is that of the α -SO₃H group in the so-called sulphonephthaleins or sulphureins. As pointed out in Part V of this work, these substances are merely sulphonic acids of benzaurine—not phthaleins at all in the strict sense: for example, they are yellow when acid and do not combine with hydroxylamine. The value of this colour-factor is 1.018. Since the factor for the CO₂H in phenolphthalein is 1.002, the factor relating any sulphonephthalein to the corresponding phthalein is 1.016, *e.g.* λ 563 for (di)phenolsulphonephthalein when phenolphthalein is λ 554. The case of catecholsulphonephthalein may be worked out from the general formula, and is instructive. This substance contains one α -SO₃H (factor 1.018); two γ -hydroxyls (factor 0.9657); and two β - or ϵ -hydroxyls (factor 1.030). The calculated wave-length is therefore $593 \times 1.018 \times (0.9657)^2 \times (1.030)^2 = 597.3$. Observation (NaHCO₃ solution) gave λ 600. The agreement is quite good enough for such a complicated case, since there are five multipliers, each of which may be wrong by 0.0005. In the case of guaiacolsulphophthalein the observation was λ 608 and the calculation $593 \times 1.018 \times (0.973)^2 \times (1.030)^2 = 607$.

Sulphuric-acid Colours.—It should be noted that although the -SO₃H group in the molecule has a colour-factor, it is not possible to explain by means of a colour-factor the behaviour of coloured substances when dissolved in strong sulphuric acid, and it must be assumed that an oxonium-salt is formed *outside* the molecule. As shown in Parts I and VI, the sulphuric-acid colours obey the different law $\frac{1}{\lambda_1} = \frac{3}{2\lambda_0} - 0.000695$, in which λ_0 is the alkaline and λ_1 the sulphuric-acid wave-length.

I have now succeeded in extending this law, which is evidently one governing change of colour by change of ionisation at or near the colour-centre, to explain the fact that benzaurine-derivatives exhibit a third colour, *viz.* in *dilute* acid. (Thus benzaurine has λ 553 in alkali [pink], λ 473 in H₂SO₄ [orange], and λ 493 [salmon] in dilute HCl, as well as the bandless yellow colour when neutral.)

Calculation of Acid Colours of the Benzaurine Family.

| | Name. | Value of λ_0 . | Calculated λ_1 . | Observed in HCl. |
|---|-----------------------------------|------------------------|--------------------------|------------------|
| 1 | Benzaurine | 553 | 494 | 493 |
| 2 | Phenolsulphophthalein | 563 | 506 | 507 |
| 3 | Catecholsulphophthalein | 600 | 553 | 557 |
| 4 | Guaiacolsulphophthalein | 608 | 564 | 565 |
| 5 | Thymolsulphophthalein | 604 | 558 | 552 |

Although the acid bands are abnormally broad and of somewhat uncertain centre, I do not think that this fact fully accounts for the discrepancies of the above table, but admit that there is probably some factor not taken account of which modifies the action of the frequency-law.

The abnormal colour of "crystal-violet" may next be considered: it has, of course, been the subject of active discussion for thirty-five years.

The following table exhibits the results of my observations on the "aniline dyes" in presence of alkali and acid. It should be noted in regard to the mono-derivatives of fuchsene that fuchsone is insoluble both in acid and alkali, and that fuchsimine and its dimethyl-derivative are insoluble in alkali, but soluble, with colour, in acid, with bands at about $\lambda\lambda$ 430 and 460 respectively.

A. Di-derivatives of Fuchsene (all Para).

| Name. | Substituents. | Alkali A. | Acid A. | Notes. |
|---------------------------------|---------------------------------|-----------|--------------|-----------------|
| Benzaurine | Two OH | 553 | 494 | — |
| Aminofuchsone | One OH, one NH ₂ | 558 | ? | — |
| Doebner's violet | Two NH ₂ | — | 562 | Nearly neutral. |
| Benzaurine | Two OH | 553 | 494 | — |
| Dimethylaminofuchsone | One OH, one NMe ₂ | 586 | 515 broad | ? 500 + 530 |
| Malachite-green | Two NMe ₂ | — | 619 | Nearly neutral. |

B. Tri-derivatives of Fuchsene (all Para).

| Name. | Substituents. | Alkali A. | Acid A. | Notes. |
|--|---------------------------------|-------------------------------|---------|-------------------------------|
| Aurine | Three OH | 534 | 485 | Also 503 + 548, then neutral. |
| Paeonin (aminobenzaurine) | Two OH, one NH ₂ | 538 | 497 | Also 518 faint. |
| Red corallin (Diaminofuchsone) | One OH, two NH ₂ | 541 | ? | — |
| Pararosanine | Three NH ₂ | nil in alkali, 544 neutral | 575 | — |
| Aurine | Three OH | 534 | 485 | — |
| Dimethylaminobenzaurine | Two OH, one NMe ₂ | 575 | 500 | Interpolated. |
| Bis-dimethylaminofuchsone (oxymalachite-green) | One OH, two NMe ₂ | 580 | 607 | — |
| Crystal-violet | Three NMe ₂ | nil in alkali, 595 neutral | 632 | — |

We note that the normal colour is in alkali in OH-compounds, and in acid in amino-compounds, yet nevertheless the differences in colour are regular, e.g. 553, 558, 561 : 553, 586, 619 : 534, 538, 541, 544 : 534, 575,

580, 607, 632. It is unfortunate that the series is incomplete; but on the existing evidence it seems that the change of colour takes one regular path in neutral solution, and another, equally regular but different, in acid solution. This amounts to the assumption that there are separate colour-factors for the ionised $-\text{NH}_3^+$ and $-\text{NHMe}_2^+$ groups different from the factors for $-\text{NH}_2$ and $-\text{NMe}_2$, and there the matter may rest until the lacunae in the evidence are filled.

There are other lacunae in a complete colour-scheme for triphenyl-carbinol-derivatives, namely, colour-factors for groups and positions which occur only once. In a special investigation of benzaurine-derivatives I have endeavoured to find approximations to the values of most of the remaining colour-factors, and the results are given below:

| | Name of substance. | Source. | λ . | Name of colour-factor. | Value of factor. |
|----|------------------------------|-----------------------------------|-------------|------------------------|------------------|
| 1 | α -bromobenzaurine | Orthobrombenzoic acid and phenol | 568 | α -bromo | 1.027 |
| 2 | β -bromobenzaurine | Metabrombenzoic acid and phenol | 565 | β -bromo | 1.022 |
| 3 | γ -bromobenzaurine | Parabrombenzoic acid and phenol | 539 | γ -bromo | 0.975 |
| 4 | Phenolisophthalein | Isophthalic acid and phenol | 560 | β -carboxyl | 1.012 |
| 5 | Phenoltterephthalein | Terephthalic acid and phenol | 550 | γ -carboxyl | 0.995 |
| 6 | Metasulphobenzaurine | Metasulphobenzoic acid and phenol | 560 (vague) | β -sulphonyl | 1.01 |
| 7 | Parasulphobenzaurine | Parasulphobenzoic acid and phenol | 568 | γ -sulphonyl | 1.027* |
| 8 | ϵ -sulphobenzaurine | Sulphonation of benzaurine | 559 | ϵ -sulphonyl | 1.010 |
| 9 | α -aminobenzaurine | Anthranilic acid and phenol | 565 | α -amino | 1.022 |
| 10 | Michler's hydrol | cf. Malachite-green | 619:603 | C-phenyl | 1.026† |

* Abnormal: less than unity expected.

† Hereby the diphenylcarbinol dyes can be calculated from fuchsene.

The δ -position in benzaurine appears to be difficult to investigate, or is possibly quite abnormal. The only substance bearing on it which I have succeeded in making is in the aurine series, and is the δ -methyl-derivative of oxymalachite green (from Michler's ketone and metaeresol). This has λ 587 when basic and λ 617 when faintly acid. Malachite-green having λ 619, we see that the combination of γ -OH and α -CH₃ is almost self-extinguishing, the factor being 0.997, so that (in the aurine series) α -CH₃ ($=\delta$ -CH₃) is about 1.030, whereas from the metaeresolphthaleins the value is about 1.026.

In conclusion, I wish to point out an extension of this colour-theory to dyes outside the triphenyl-carbinol series, *e.g.* the ratio of the wave-lengths of methylene-blue and thionine, $665 \div 602$, is the same as that of malachite-

green to Doebner's violet, $619 \div 561$, showing that the colour-factor for four methyl-groups applies also in the thiophenazine series of dyes.

ADDENDUM, 15/9/20.—Since the diphenylcarbinol dyes can be calculated from the triphenylcarbinol series by dividing by 1.026, we can next calculate the indamine dyes by finding a factor for the substitution of $-N=$ for $-CH=$ in the centre. This factor is about 1.20. Thus to calculate Bindschedler's green from malachite-green, first divide by 1.026, giving Michler's hydrol, then multiply by 1.20, giving tetramethylindamine: next from the indamines the oxazines and thiazines can be calculated. The factor is similar for both, about 0.90 for the oxo-linkage (also occurring in fluorescein) and 0.92 for $-S-$ linkage in methylene-blue. Methylene-blue calculated from malachite-green is $619 \div 1.026 \times 1.20 \times .92 = 665$.